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A Comprehensive Guide to Traffic Flow Modeling and Simulation of Traffic Flow Behavior under Mixed Condition

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ABSTRACT
Study of the basic traffic flow characteristics includes analysis of the movement of different vehicles and the interactions they make with one another. For better representation and understanding of traffic flow behavior, fundamental relationships have been established among the traffic characteristics and the knowledge of which is an essential requirement in planning, design, and operation of roadway facilities. Traffic engineers assess the roadway traffic and its impact on proposed traffic flow system and identify primary locations and causes of deficiencies in order to improve the existing roadway system. All these tasks may be successfully accomplished only through a firm framework, which requires better understanding of traffic flow characteristics and their interdependences. The research work presented here is related with the study of microscopic and macroscopic traffic flow characteristics on multilane highways under heterogeneous traffic conditions. The research uses field data collected on various sections of multilane highways for analyzing traffic characteristics and the same data is used as inputs for modeling traffic flow behavior on a simulated platform.

I. INTRODUCTION

India has second largest road network in the world having the length of over 5.603 million kilometers as on 31st March 2016 (www.morth.nic.in). The National Highways (NH) are the primary long-distance roadways running through the length and breadth of the country, connecting all major cities and ports, state capitals, large industrial and tourist centers, etc. National Highways constituting length of over 1.01 million kilometers. Even though the National Highways represent only about 1.76% of the total road network length, they handle about 40% of the total road network (www.nhai.org). National highways in India are designated as NH, 'followed by the highway number'. The analytical process consists of predicting an output as a function of specified inputs. This analytical process can vary from simple equation to a comprehensive simulation model. The important issues for analysts are their knowledge of the system being considered including its flow characteristics, and of analytical techniques and their appropriate selection for the problem at hand. Microscopic analysis may be selected for small or moderate-sized systems, where the number of transport units passing the system is relatively small and there is a need to study the behavior of individual units in the system (e.g. midblock section of a particular roadway, intersection on a particular roadway, etc.). Macroscopic analysis may be selected for larger scale systems, in which a study of the behavior of units is sufficient (e.g. city level or regional level road network). The present work is on multilane divided highways with unidirectional traffic on both sides of the median. The study is restricted to straight sections of intercity highways with heterogeneous traffic flow. The study considers both paved and unpaved shoulder sections.

II. LITERATURE REVIEW

Schul (1955) suggested the modifications to Poisson's distribution model for defining the rare events of traffic flow under homogeneous traffic conditions. The set of spacing between successive vehicles arrival was assumed to consist of subsets, each with a different mean and following Poisson law. The results obtained from modification of Poisson distribution showed agreement with the observed field data.

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Weiss and Herman (1962), Breiman (1963), Brown (1972), Newell (1955, 1966) and Thedeen (1964) established the conclusion that the negative exponential distribution usually defines the headway distribution for traffic flows with unrestricted overtaking.

Lewis (1963) developed a model to determine the arrival time of a vehicle. The suggested model was based on the binomial distribution with two different probabilities of arrivals and it also incorporated the platooning effect of traffic stream.

Dawson and Chimni (1968) proposed a hyperlang model to describe free and constrained headways of vehicles in traffic flow stream. They suggested the distribution with a linear combination of translated exponential function (for free headways) and translated Erlang function (for constrained headways). The proposed Hyperlang distribution was fitted to the headway data at different volumes collected on sections of two-lane two ways roads.

Tolle (1971) considered lognormal distribution with three parameters for defining field headway distributions. The headway data for the study were collected on Interstate 71, Ohio in a volume range of 800-1900 vph. The graphical analysis revealed that with the increasing volume, headway frequencies tend to skew more towards left with less dispersion. At 5% level of significance, Chi-square test showed a good fit only under the volume ranges of 800 to 1200 vph, 1400 to1500vph and 1700 to 1800 vph respectively. However, Kolmogorov-Smirnov test conducted for goodness-of-fit has provided a good fit for the whole range of observed volume i.e. 800-1900vph.

Wasielewski (1974) reformulated the Semi-Poisson headway distribution model proposed by Buckley (1962, 1968) and derived an integral equation for calculating the constrained component directly from the observed headway distribution without introducing a parametric for the follower distribution.

Mahalel and Hakkert (1983) developed a model describing the sequence of vehicle arrivals in adjacent lanes of a multilane highway as a Markov renewal process. It was concluded that the presence of a vehicle in a particular lane, increases the chances of next vehicle arrival on the adjacent lane.

Ramanayya (1988) considered negative exponential distribution for highways at volumes less than 500 vph, shifted exponential distribution at 500 to 650 vph and log-normal distribution at 650 to 900 vph.

Mei and Bullen (1993) analysed headway distribution under higher traffic flow (2,500 to 2,900 vehicles/day) conditions on freeway section. The shifted lognormal distribution with a shift of 0.3 s or 0.4 s has provided a good fit for headway data.

Akcelik and Chung (1994) discussed negative exponential, shifted negative exponential and bunched exponential distributions for arrival headways. Bunched exponential distribution was found to produce more realistic results for both single lane and multi-lane traffic streams as compared to other two distributions.

Sahoo et al. (1996) studied the traffic flow characteristics on two stretches of NH-5 near Bhubaneswar city in Orissa. The negative exponential distribution was found to be in close agreement with the observed headway data.

Kumar and Rao (1998) analyzed the observed headway data at locations of NH 5 and NH 6 in India. Chi-square test was performed at 5% significance level to ascertain the goodness of fit between the observed and theoretical frequencies. They found that the negative exponential distribution closely represents headway patterns for volume levels varying from low to moderate. A composite distribution which combines normal distribution (for vehicles in platoons) and shifted negative exponential distribution (independent vehicles) was suggested for higher traffic volumes.

Chandra et al. (2001) analyzed the inter-arrival pattern of vehicles on a six-lane divided highway in New Delhi by using artificial neural network. The influence of traffic composition and volume on headway was studied. Headway between same vehicle categories found to be decreased with increase in traffic volume and their proportions in the traffic stream. A minimum headway of 1.72 s was recorded for all cars situation. Moreover, Chandra and Kumar (2001) collected the headway data on six-lane divided urban roads in New Delhi for further studies. Exponential distribution, lognormal distribution and hyperlang distribution were employed to fit the observed headway data collected on different sites. It was found that hyperlang distribution adequately fitted the data under volume range from 900 to 1600 vph. Minh et al. (2005) studied motorcycle behaviour in Hanoi city of Vietnam. They collected traffic flow data on both two-lane undivided and four-lane divided roadways under varying traffic and geometrical conditions. The concept of MCU (motorcycle unit) was introduced to develop the speed-volume relationship based on observed traffic flow data. The mean speed and mean

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headway were compared at selected locations using statistical F-test and t-test. Authors reported average headway as 1.16s for all four locations and a standard deviation of 0.65s. It was observed that 50% of two-wheelers were found to travel in interval range of 0.5-1.0 s headways. In spite of differences in the geometric parameters, traffic composition and operations, all the four locations were reported to have same mean headway.

Xue et al. (2009) analysed time-headway distributions on expressways in Beijing, Shanghai, and Guangzhou cities, China. The time-headway data were collected on a typical weekday for this study during 6:00 a.m. and 6:00 p.m. This study identifies three types of distributions that best fit the headway data. It is found that the sections having traffic volume less than 250 vph fits negative exponential distribution to headway data. For traffic volume ranging 250 to 750 vph, data follows a sifted negative exponential distribution. And, for traffic volume ranging 750 to 1,500 vph, the time headways can be modeled with Cowan's M3 distribution model.

Panichpapiboon (2015) investigated the time-headway distributions of vehicles travel on an urban expressway in Bangkok, Thailand. Author characterized headway distribution and concluded that GEV distribution is most effective in modelling time headways. However, the exponential distribution was found to be the least effective distribution under heavy traffic volume.

III. SELECTION OF STUDY LOCATIONS

Field data for study was collected at different mid-block sections of multilane divided intercity highways. Location of highways where data was collected are parts of National Highway (NH) exists on plain terrain with straight alignment, some sections are access control and some are partially access controlled in both the directions of travel. Details of the study sections have been given in the Table 4.1. Section I, Section II and Section III are located on NH 163 near Madikonda village, Bibinagar village and Ghanpur village respectively. However, these sections are differs from the type of access control. Section-I has no access control and Section-II has fully control of access whereas Section-III is partially access controlled. Section IV is NH45A (NH332, as per new numbering) connecting Chennai to Nagapatinam, near Viluppuram district, in Tamilnadu State. Section-V is a part of NH 58 located in between Delhi and Meerut city near Modinagar. Section VI is located on NH 24 connecting Delhi and Harpur cities. Section-VII and Section-XI are located on NH 16 between Guntur and Ongole cities respectively, which is a six- lane divided intercity highway having 1.8 m paved shoulders. Section-VIII is selected from NH 8 near Delhi, which is an eight-lane divided intercity highway having 1.8 m paved shoulders. The snapshot of study sections are shown in Figure 3.1 to Figure 3.3.

Table 3.1 Details of the study sections

Sections	Highway No.	Location	Type of highway	Type of Shoulder	Properties	Posted speed limit (Kmph)
I	NH 163	Kakinada (Andhra pradesh)	Four lane Divided	Paved	CW: 7.0 m SW: 1.5 m	80

*CW-Carriageway width, SW-Shoulder width

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Figure 3.1 section of four-lane divided highway with paved shoulders (section-2)

Figure 3.2 Section of six-lane divided highway with paved shoulder (section-VII)

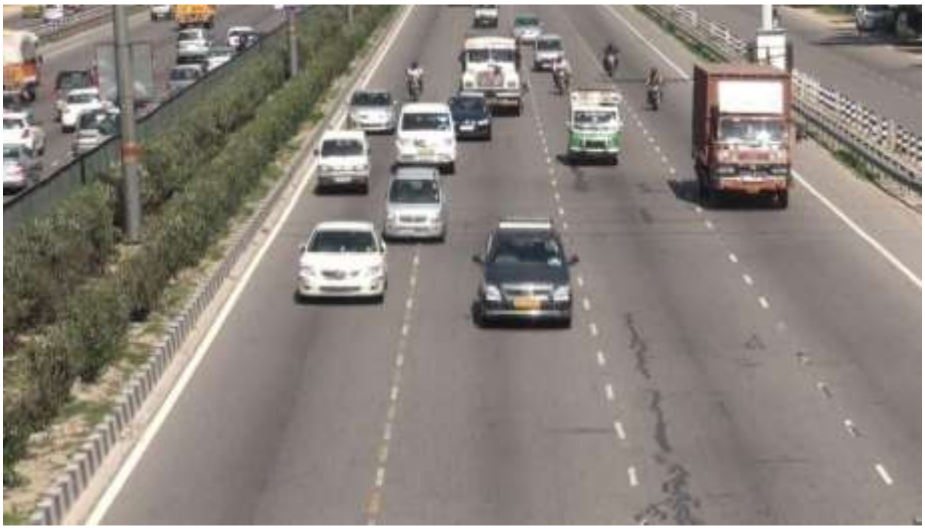

Figure 3.3 Section of eight-lane divided highway with paved shoulder (section-VIII)

3.1 FIELD DATA COLLECTION & CALCULATIONS

3.1.1 SPEED AND VALUME DATA

The videography technique was used to record the movements of vehicular traffic in one direction of travel. Two thick white lines with clear visibility were marked on the pavement to make a longitudinal trap on the highway section by using a self-adhesive cloth tape. A distance of 60-100 m was selected for the trap (depending upon the

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posted speed limit of highway) which would eventually act as reference lines for measurement of speed. However, the traffic volume count was made based on the one of reference lines. A high definition video camera was placed on a tripod at suitable vantage point and recording was done continuously for 6.00 to 8.00 hrs on typical weekdays in clear weather conditions.

3.1.2 VEHICLE ARRIVAL AND TIME HEADWAY DATA

The video recording technique was used to record the traffic flow operations to obtain vehicle arrival data as well. A thick white line with clear visibility was marked across the road for providing a reference line to measure vehicle arrival frequency. The time difference between the two consecutive vehicles (front bumper) was calculated to obtain the time headway.

3.1.3 LATERAL PLACEMENT CHARACTERISTICS

The lateral position of vehicles across the whole carriageway width was also noted by videography technique. The pavement width was divided into sections of 25 cm width using self-adhesive tape and these were numbered from 0 to 28 starting from pavement edge to the highway median. The positions of vehicle types were recorded by noting down the strip number over which vehicles placed its left wheel while traversing the highway section.

3.1.4 OVER TAKING CHARACTRISTICS

Floating car method was used for collecting the data. The data were collected on typical weekdays with normal weather conditions. The process of overtaking operation was divided into 5 events and recorded the time taken for each event (Chandra and Shukla, 2012). The description of events recorded during data collection is described as under.

Event 1: When the overtaking vehicle deflects to the adjacent lane for starting the maneuver.

Event 2: When the front bumper of the overtaking vehicle is in line with the rear bumper of the test vehicle.

Event 3: When the front bumper of the overtaking vehicle is in line with the front bumper of the test vehicle.

A Tata Indigo car (Diesel) was used as a test vehicle for collection of data. The vehicle was driven at different constant speed on a stretch of 2 km for recording of above events and maneuvers. A team of three persons were appointed in the car to record the data. The first person was sitting on the back seat of test vehicle and recorded the type of overtaking vehicle and the speed of test vehicle during each overtaking maneuver.

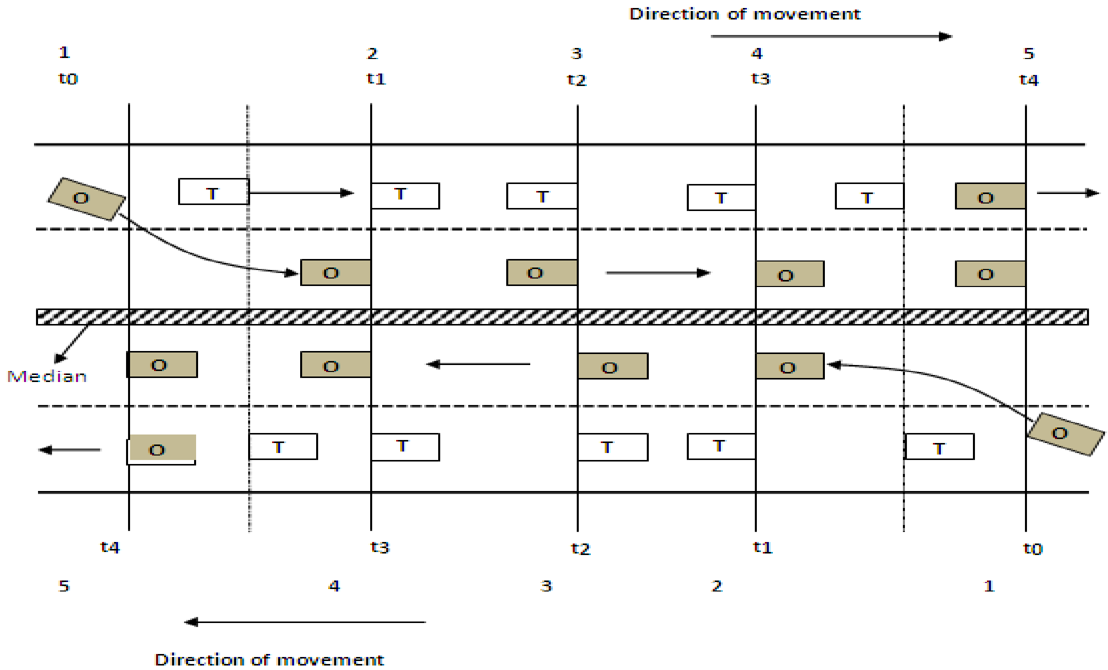


Figure 3.4 Details of events during overtaking/lane-changing operation

Table 3.2 Fitting of Poisson distribution to arrival data at Section-I

Number of vehicles in 20 sec interval (x)	Observed frequency (Of)	(x ×Of)	$((x-\mu)^2 \times Of)$	Estimated frequency by Poisson distribution (Ef)	Ef (after Pooling)	Of (after Pooling)	$\chi^2 = \frac{(Of-Ef)^2}{Ef}$
0	3	0	52.78	3	--	--	--
1	14	14	142.86	11	14	17	0.64
2	24	48	115.57	24	24	24	0.00
3	39	117	55.64	33	33	39	1.09
4	23	92	0.87	35	35	23	4.11
5	33	165	21.41	30	30	33	0.30
6	16	96	52.16	21	21	16	1.19
7	13	91	102.32	13	13	13	0.00
8	8	64	115.86	6	10	15	2.50
9	3	27	69.28	3	--	--	--
10	3	30	101.11	1	--	--	--
11	1	11	46.32	0	--	--	--
	180	755	876.19	180			9.83

Null hypothesis H0: Arrival pattern observed at Section-I follow Poisson distribution.
Alternative hypothesis H1: Arrival pattern observed at Section-I does not follow Poisson distribution.

Mean rate of arrival $(\mu) = \frac{\sum(x \times Of)}{\sum Of}$ = 4.194 sec

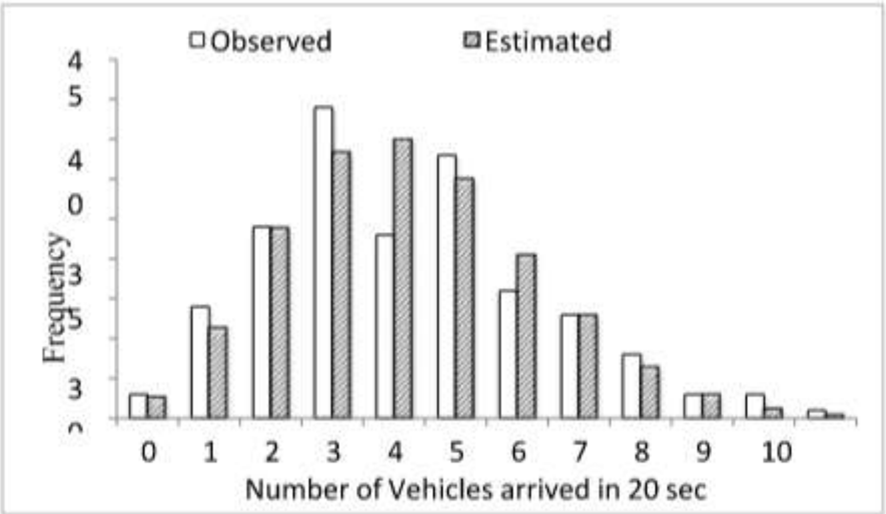
Variance of arrivals (σ^2) from mean = $\frac{\sum((x-\mu)^2) \times Of}{\sum Of - 1}$

= 4.895 sec

Degree of Freedom (υ) = 8-2 = 6

At, υ = 6 and α = 5%

χ^2 (tabulated) = 12.59
χ^2 (calculated) < χ^2 (tabulated)
Hence, null hypothesis H0 is accepted.



3.1.5 Statistical distributions for time headway

Brief descriptions of statistical distributions tried to fit the observed time headway data are given in this section.

GENERALIZED EXTREME VALUE (GEV)

The Generalized Extreme Value (GEV) distribution is a flexible three-parameter model that combines the Gumbel, Frechet, and Weibull maximum extreme value distributions. It has the following probability density function (PDF).

$$f(x) = \begin{cases} \frac{1}{\sigma}\exp\left(-(1+kz)^{-1/k}\right)(1+kz)^{-1-1/k} & k \neq 0 \\ \frac{1}{\sigma}\exp(-z-\exp(-z)) & k = 0 \end{cases}$$

Where z=(x-μ)/σ, and k, σ, μ are the shape, scale, and location parameters respectively. The scale must be positive, the shape and location can take on any real value.

A shape parameter, as the name suggests, affects the general shape of a distribution. The Location parameter tells about where the distribution is centered on the horizontal axis. The Scale parameter gives an idea of the scale on the horizontal axis.

PEARSON (6) DISTRIBUTION

There are two versions of this distribution: two-parameter Pearson 6 and three-parameter Pearson 6 distributions. It has the following probability density function.

$$f(x) = \frac{((x-\gamma)/\beta)^{\alpha_1 - 1}}{\beta\, B(\alpha_1, \alpha_2)\,(1+(x-\gamma)/\beta)^{\alpha_1+\alpha_2}}$$

Where, α1,α2 are shape parameters and β,γ are the scale, and location parameters respectively.

γ=0 yields the two-parameter Pearson 6 distribution. The scale, shape parameters must be positive, and location can take on any real value.

GAMMA DISTRIBUTION

There are two versions of this distribution: two-parameter Gamma and three-parameter Gamma distributions. It has the following probability density function.

$$f(x) = \frac{(x-\gamma)^{\alpha-1}}{\beta^{\alpha}\,\Gamma(\alpha)} \exp\left(-(x-\gamma)/\beta\right)$$

Where, α,β and γ are the shape, scale, and location parameters respectively. γ=0 yields the two-parameter Gamma distribution. The scale, shape must be positive, and location can take on any real value.

3.1.6 STATISTICAL ANALYSIS OF TIME HEADWAY

The time headway data of each vehicle observed in recorded videos were extracted in 20 sec. interval. The descriptive analysis was performed with extracted data to understand its basic characteristics. The parameters those describe the basic characteristics such as mean and variance of data are given in the Table 3.3 for Section-I, Section-V and Section-VII respectively.

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Table 3.3 Descriptive parameters of time headway data

	Section-I	Section-V	Section-VII
Mean (sec)	4.48	2.41	2.98
Median (sec)	3.71	1.71	2.21
Standard deviation (sec)	3.31	2.09	2.49
Sample size (N)	590	1400	1100

It is known that the time headway of vehicles is affected by the traffic volume observed on highway section. It has also been observed that the mean time headways, median values and standard deviation found to be decreased with increase in traffic volume ranges. The decreasing trend clearly indicates that the proportion of free-flowing vehicles is lesser in high volume a range which is resulted in smaller time headways. However, in all cases the median values of time headways are found to be smaller than the mean, infers more than 50% of drivers chose time headways lesser than their mean values.

Table 3.4 Average time headway (sec) of vehicle types

Vehicle Type	Section-I	Section-V	Section-VII
CS	3.96	1.83	2.69
CB	4.04	1.73	2.72
LCV	4.10	1.83	2.78
HV	4.16	2.17	2.76
MAV	4.66	3.63	2.77
TW	4.48	2.07	2.68
3W	4.43	1.64	2.76
B	4.58	2.64	2.72

In order to fit different probability distribution functions to the time headway data, 5% of long time headways may be neglected and statistical results for different flow levels will be evaluated by considering 95%-time headway values. In the present study, goodness of fit for each probability density function is tested by performing Kolmogorov-Smirnov (K-S) test at 5% significance level. The results of time headway distributions analysis for different study sections based on K-S test are given in Table 3.5.

Table 3.5 Estimated parameters of the best fitted distributions for Time headway data at different study sections

Sections	Best fit	Parameters	K-S Test Value	K-S Test Critical Value
I	Pearson6	α1=1.53 α2=89.8 β=26158.0	0.04166	0.05581
	Gamma	α=1.46 β=3.057	0.04429	
	Weibull	α=1.1238 β=5.0426	0.04470	
V	GEV	k=0.258 σ=1.096 μ=1.402	0.03587	0.03618
VII	GEV	k=0.159 σ=1.59 μ=1.76	0.03495	0.04096

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From Table 3.5, it is observed that Pearson 6 is found to be the best fit for headway data on Section-I whereas, Generalised Extreme Value (GEV) distribution is fitted best to the time headway data observed on Section-V and Section-VII. In addition, Gamma and Weibull distributions are also found suitable to fit time headway distribution at Section-I. Figure 5.4 to 5.6, provides the PDF profile of fitted distribution to respective highway sections.

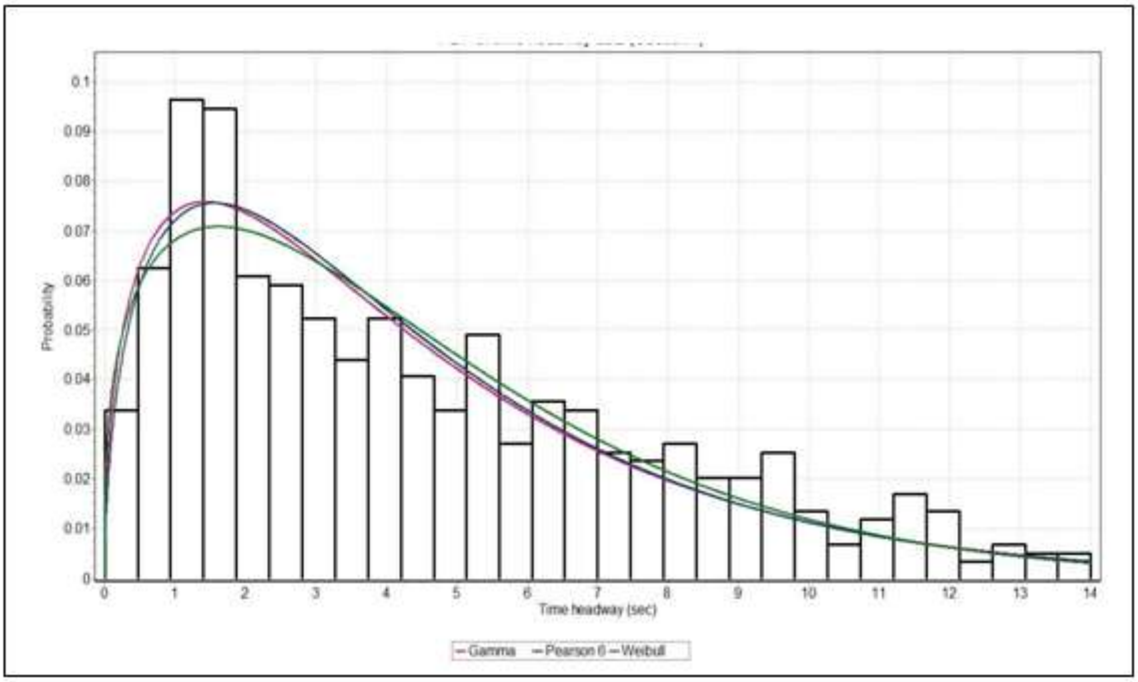

Figure 3.4 Time headway distribution profile at Section-I

3.1.6 SPEED DATA ANALYSIS

Speed data was collected using video recording method at 1 different roadway sections on multi- lane divided highways in India. Two thick white lines were marked across recorded videos and played on a wide screen computer system. Speed of individual type of vehicles was extracted by noting down the time taken by a vehicle to cross a longitudinal trap length using electronic stop watch with 0.001s accuracy. Speed related parameters such as 15th, 50^{th} and 85th percentile speed were estimated and analysed by developing box plots. Figure 5.7 presents the box plot developed using speed percentiles estimated at each section of selected highways.

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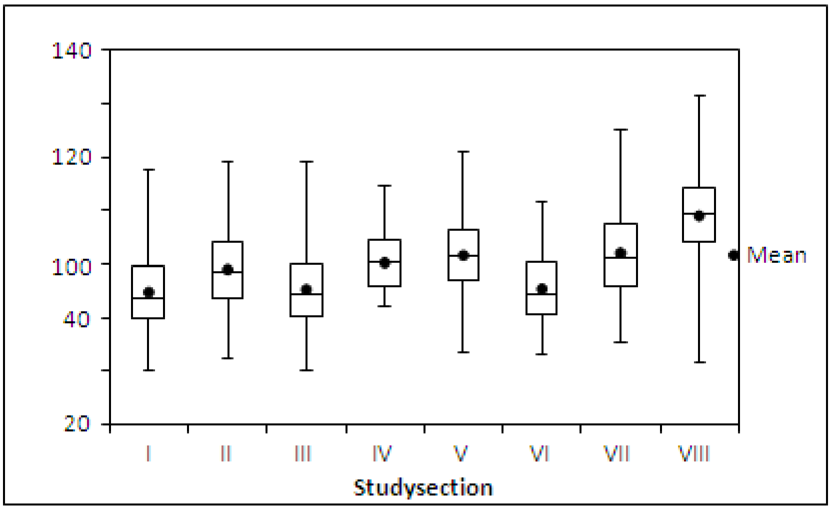

Figure 3.5 Box plot of speed percentile of vehicles at study sections

Speed raw data of each vehicle type was used to find mean and other related parameters such as 15th, 50th and 85th percentile speed of each vehicle type at 8 study locations and are given in below Table

Sections	**Vehicle type**	**Mean speed (km/h)**	**Maximum speed (km/h)**	**Minimum speed (km/h)**	**Standard Deviation (km/h)**	**V15 (km/h)**	**V50 (km/h)**	**V85 (km/h)**
I	**CS**	64.50	95.54	28.88	12.12	52.44	65.06	77.03
	CB	67.00	92.07	34.97	11.73	55.59	67.35	78.46
	TW	45.10	82.72	21.27	10.70	34.29	44.36	55.65
	3W	40.80	56.41	20.00	7.11	33.95	41.47	48.11
	LCV	47.56	83.06	21.63	12.88	35.00	46.12	61.12
	HV	42.10	62.39	21.47	9.90	30.18	42.49	51.94
	MAV	39.10	63.22	25.57	8.26	29.85	38.72	48.48
	B	45.20	64.15	22.81	8.08	37.93	44.61	52.30

Table 3.6 Speed parameters for vehicle types at different sections

3.1.7 PCU ESTIMATED BY AVAILABLE METHODS

The field data collected at Section-I and Section-VII used for estimation of PCUs of different vehicle types by Homogenisation Coefficient Method, Headway Method, Simultaneous Equation Method, Multiple Linear Regression Method and Dynamic PCU Method. Details of these methods were explained in APPENDIX-A. PCU values of different vehicle types on Section-I and Section-VII estimated by various methods are shown in Table 5.13 and Table 5.14.

Table 3.7 PCU values of different vehicle types on Section-I

Methods	Passenger Car Unit(PCU)						
	CB	3W	HCV	MAV	LCV	TW	B
Homogenisation Coefficient Method	1.24	1.39	2.92	5.74	1.63	0.77	4.31
Headway Method	1	1	11.05	11.05	1	1	11.05
Simultaneous Equation Method	4.02	6.03	-5.03	2.02	6.27	-0.04	-8.11
Multiple Linear Regression Method	-10.19	13.7	34.67	-12.95	30.72	21.91	34.72
Dynamic PCU Method	1.26	1.05	3.96	8.21	1.51	0.34	5.00

3.1.8 ESTIMATION OF PCU

The PCU value of a subject vehicle type is estimated as the product of speed factor, headway factor and area factor. The average speed data and average time headway data of vehicles are used to estimate PCUs. The data used for PCU estimation has been provided in the previous sections. Correlation analysis was performed between speed and headway data. The correlation coefficient values obtained between speed and headway data obtained from the Section-I, Section-V and Section-VII are -0.12, -0.09 and -0.15 respectively. Statistically weak correlation was found between the speed and headway data hence there is no dependency found between speed and headway of vehicles.

Table 5.16 PCU values of different vehicle types by modified method on Section I

Vehicle Type	Speed factor	Headway factor	Area factor	PCU
CB	0.963	1.021	1.299	1.28
LCV	1.355	1.034	1.100	1.54
HV	1.532	1.049	2.525	4.06
MAV	1.650	1.175	4.566	8.85
TW	1.430	1.131	0.239	0.39
3W	1.581	1.118	0.667	1.18
B	1.427	1.156	4.184	6.90

IV. CONCLUSIONS

The following conclusions are drawn from the present study.

1. Different methods given in the literature to calculate PCU value of vehicle types are not found realistic under the traffic flow conditions as observed in field. However, homogenization method and dynamic PCU method have provided better results.
2. Modification to dynamic PCU method done by adding the time headway factor has given realistic results. The modified dynamic PCU method provides relatively higher values for large vehicle types than those obtained from dynamic PCU method.
3. A new multiple non-linear regression (MNLR) method has been developed to estimate more accurate equivalency units of a subject vehicle type under highly heterogeneous traffic conditions.
4. Normal distribution failed to fit the lateral placement data observed in the field as the placements of vehicles was found more on the inner lanes because fluctuations observed along width of road in field data.
5. While testing simulation parameters, random seed numbers (RSN) which has potential to alter the simulation results are found to be insignificant to influence volume outputs when tested at 5% level of significance. However, the RSN value giving the least percentage error between the field and simulated volume was used in the study.
6. Sensitivity analysis performed by altering driving behavior model parameters namely CC0, CC1 and CC2 are found to be influential on simulated capacity at 5% level of

significance. As CC1 parameter value increases the simulated capacity reduces consistently.

7. A capacity equation formed based on multiple linear regression model to find value of target capacity by providing CC0, CC1 and CC2 parameters as inputs. The study suggests the range of CC0, CC1 and CC2 parameters as 0.50 to 4.9, 0.45 to 1.63 and 2.1 to 8.3 respectively, to be given as inputs for simulating multilane highway section to achieve target capacity.
8. Lane changing of vehicles found as an important parameter which has a significant effect on capacity of multilane highways. Frequency of lane changes are found to be increased gradually as traffic volume increased on simulated section up to some extent. Further, decrease in lane changes were observed as traffic volume reached to higher level. However, no further increase or decrease was observed in lane changes of vehicles at capacity level of volume. It is concluded that if traffic volume level reaches to capacity, lane changing opportunity of vehicles reduces due to unavailability of vacant spaces on a roadway.
9. The value of maximum lane changes was estimated separately on simulated four-lane, six-lane and eight-lane sections. It increases with increase in proportional share of 2Ws and reduces with the increase in proportional share of heavy vehicle (HV) in under mixed traffic. Maximum lane changes found to increase with increase in addition of extra lanes to the directional traffic stream. Moreover, maximum lane changes are found inversely proportional to the proportional share of HV and it increases linearly from four-lane to eight-lane divided sections.
10. Maximum numbers of lane change on a highway is found depended on vehicle types sharing their respective proportions in the mixed traffic stream. Present study proposed as general model to quantify the maximum lane change capacity of mixed traffic stream over 1 km length of highway.

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