Global Journal of Researches in Engineering: E
Civil And Structural Engineering
Volume 14 Issue 3 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Analysis of Headway of Heterogeneous Traffic on Indian Urban Roads

By Mr. V Suresh, Dr. R Sivanandan. & Dr. G Umadevi
Anna University, India

Abstract- Headway or inter-arrival time of vehicles is an important parameter in traffic flow, especially in urban roads, since this is one of the main parameters to determine the minimum (safe) gap between vehicles and the capacity. The studies done on headway analysis have mostly concentrated on homogeneous traffic where the flow follows lane discipline. This ideal situation does not exist on Indian urban roads, where the traffic is very heterogeneous, and do not follow lane discipline. A study of headway at different but similar locations of urban four lane divided (two lanes for each direction of flow) roads of a metropolitan city in India (Chennai) was made. The peak hour flow at these locations were observed to be high (varying from 3189 to 9987 vehicles). The study of headway, after removing the 5 % of long headways, at these location indicate that Log normal 2, Inverse Gauss and the Exponential distributions are the most appropriate ones for these conditions of flow. An attempt was made to study the individual inter arrival time of each category of vehicles in the traffic stream. Extensive data extraction was done and the analysis of headway of categorized traffic was made. Appropriate distribution for each category is recommended. The study will be a good input for modeling vehicle generation in simulation studies.

GJRE-E Classification : FOR Code: 090599

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Mr. V Suresh [α], Dr. R Sivanandan. [σ] & Dr. G Umadevi [ρ]

Abstract- Headway or inter-arrival time of vehicles is an important parameter in traffic flow, especially in urban roads, since this is one of the main parameters to determine the minimum (safe) gap between vehicles and the capacity. The studies done on headway analysis have mostly concentrated on homogeneous traffic where the flow follows lane discipline. This ideal situation does not exist on Indian urban roads, where the traffic is very heterogeneous, and do not follow lane discipline. A study of headway at different but similar locations of urban four lane divided (two lanes for each direction of flow) roads of a metropolitan city in India (Chennai) was made. The peak hour flow at these locations were observed to be high (varying from 3189 to 9987 vehicles). The study of headway, after removing the 5 % of long headways, at these location indicate that Log normal 2, Inverse Gauss and the Exponential distributions are the most appropriate ones for these conditions of flow. An attempt was made to study the individual inter arrival time of each category of vehicles in the traffic stream. Extensive data extraction was done and the analysis of headway of categorized traffic was made. Appropriate distribution for each category is recommended. The study will be a good input for modeling vehicle generation in simulation studies.

I. Introduction

Headway or Inter arrival time is a measure of the temporal space between two vehicles. Specifically, the headway is the time that elapses between the arrival of the leading vehicle and the following vehicle at the designated test point. You can measure the headway between two vehicles by starting a chronograph when the front bumper of the first vehicle crosses the selected point, and subsequently recording the time that the second vehicle's front bumper crosses over the designated point. Headway is usually reported in units of seconds.

The distribution of these headways has long been a subject of study. Even though several attempts have been made to find the distribution of headways under homogeneous traffic following lane discipline, the studies under mixed traffic conditions are very few. The distribution tried for flow under homogeneous conditions include negative exponential, shifted exponential, gamma, erlang, log-normal etc for varying traffic volume.

Author α: Research Scholar, Anna University, Chennai. e-mail: sureshv@iitm.ac.in
Author σ: Professor, Department of Civil Engineering, Indian Institute of Technology Madras, Chennai. e-mail: rsiva@iitm.ac.in
Author ρ: Assistant Professor, Department of Civil Engineering, Anna University, Chennai. e-mail: gudevi1@yahoo.co.in

For traffic prevailing under mixed conditions, where the full width of the road is used by all category of vehicles, from cycle/carts to heavy trucks/trailers, with almost equal priority, there has not been any detailed study done so far. Some attempts made for mixed conditions report that the exponential, erlang, normal and log-normal distributions for various volume levels are appropriate.

II. Literature Review

Isaac and Veeraraghavan (1) have attempted to study the headway distribution under mixed traffic flow conditions. Various distribution models like Negative exponential. Shifted negative exponential, Erlang, Log-normal, Double exponential (Schul's model) and Tripple exponential models were tried and they have reported that no definite conclusion can be arrived regarding the suitability of the models for different volume levels and the percentage composition of vehicle types. It is also reported that the variation in width of the road do not have influence on the distribution. The study has also suggested that the exponential distribution (for flow less than 500 vph), Shifted exponential distribution (for 500 – 2000 vph) and Erlang or composite distribution (for 2000 to 3000 vph) may be adopted for a mixed traffic flow (for a composition of about 20% of 4-wheerlers. 30% autos and 5 % two wheelers):

A study by Chang and Kim (2) has analysed the quantitative methods to define capacity by evaluating the headway and volume distribution from observed traffic flow. Statistical distributions of observed traffic flow were used to remove long headways and reduced cumulative distribution of volumes were only. The authors have said that the rational alternative is to take the 95 % cumulative distribution of observed traffic flow, eliminating 5 % of long headways.

Reddy and Issac (3) have attempted to calculate the practical capacity values of some selected sections on urban roads based on headway analysis. The practical capacity has been calculated based on weighted mean, median, mode and lower mean headway of different classes of vehicles at different volume levels. It was observed that negative exponential distribution is found to be fitting well for vehicle volume less that 720 vph, whereas Erlang distribution fits well at higher volume level of 1440 to 2880 vph.

Hoogendroorn and Bovy (4) have extended the generalised queueing model (GQM) to headway

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observations, segregated according to vehicle type. The estimation method developed is based on the minimization of an integrated squared error distance in the frequency domain. In this study, a new approach for modeling mixed- vehicle- type headway distributions is presented. The model is a straightforward modification of the GQM and distinguishes among different vehicle types (eg. Passenger cars articulated trucks, unarticulated trucks, recreational vehicles, motorbikes). It was expected that because of differences in driving behaviour among vehicle types, bike-type specific headway distributions will exhibit different parameter values.

Arasan and Koshy (5) have reported that the negative exponential distribution is adequate to model headways. It was observed that even during medium and heavy flow conditions, the flow is unconstrained for a considerable proportion of smaller vehicles (two wheelers) and thus their arrivals are in the random state.

Katti and Pathak (6) has analysed various headway distribution models for urban roads under mixed traffic conditions. It was observed that opportunities for passing depend upon the width of the road and vehicle size, which has direct influence on the choice of the headway model.

According to Satish (7), the exponential and log-normal distributions are not able to describe headway distribution under mixed traffic conditions. The hyp distribution is found to be sound and quite versatile for this purpose and can be fitted to a wide range of traffic volumes.

The case study of time headways from Riyadh by Ali-Ghamdi (8) indicate that though observed headways at arterial sites follow a Gamma distribution, distributions that fit freeway headways differ according to the traffic flow state. The Erlang distribution provides a good fit to the observed headway at sites with high traffic flows.

The studies so far made for heterogeneous traffic flow do not clearly indicate the characteristics of headway pattern. Also the concurrence flow of several types of vehicles was not studied in detail. Hence in this study, an in depth study and analysis of headway distribution are made to have a better understanding.

III. Data Collection

The data for the present study was collected at ten mid block sections of four lane divided (2 lanes on either side) roads in Chennai city. The video recording technique was used to collect the data. A reconnaissance survey was done initially to select the site. The mid block stretches selected were straight, level and free from any obstructions/restrictions to traffic movement. There were raised foot path on either sides and the divider was fixed.

The road stretches were selected so that the carriageway widths varied from 6.5 m to 9.0 m. ie, + /– 1.5 m of the standard two lane urban road of 7.5 m. The road links were identified based on the traffic and their characteristics. To have a good representation of the whole study area, i.e. the Chennai city, the road stretches were selectively chosen from the three parts of the city ie. South, North and Central. Based on the city road map and discussion with experts, the first list of locations was drawn. A reconnaissance survey of all the road links was made to see the actual site conditions and the geometrics. The exact survey locations were frozen after ascertaining that the flow is even and the stretch is divided for a substantial length without any obstructions like bus stops, signals. The video recording technique was used to collect the data. The place for fixing the camera was also selected. A longitudinal trap length of about 30 m was adopted to capture the data for the measurement of speed. Markings were made with paint on the road to fix the trap length. The video camera was mounted on the tripod stand and was placed at a sufficiently high level so as to cover the full survey stretch. The data collection was done on normal sunny days (working days between Mondays through Friday). The surveys were carried out for 5 hours between 7 am and 12 noon, sufficiently long duration to cover both peak and off peak traffic. The timer in the camera was switched on to have the time recorded. In addition to the traffic data the physical data like carriageway width, footpath width, and adjoining land use were collected at the survey locations.

IV. Data Synthesis

The data collected at the site on video tapes were converted into video files and copied on to a CD. Using the "Timeint" computer programme, which records the arrival of the vehicle at the section at the stroke of a key, the inter arrival time was recorded up to 2 decimal places of a second and stored as file. The CD was run several times for creating volume/headway data files for the entire survey period for each category of vehicle. Counts were classified as heavy vehicles (lorry and tankers), buses (both private and metropolitan public transport buses), LCV (van and maxi cabs), cars, autorickshaws, powered two wheelers and cycles (including other slow moving vehicles). Using a stop watch the time taken by each category of vehicle to pass the road stretch marked at the survey location was recorded by running the CD several times for the entire survey period. The data for speed estimation was analysed for sample data, of not less than 25 percent of the total volume, to get the average speed of the traffic stream and for each category of vehicle in each five minute time interval.

Since the peak traffic on Indian urban roads are high with varying categories, and as they do not follow lane discipline, all the vehicles are free to use the available road space. There is probability of more than one vehicle crossing the reference section at the same time, indicating that the headway is zero.

The road names, carriageway width, peak hour, peak hour traffic (Nos. and PCU) are given for all the 10 survey locations in Table 1. The traffic compositions at these locations are given in Table 2. The percentage share of motorized two wheelers was found to high varying from .. to ..

Most of the studies done on analysis of headway distribution have examined vehicular flow in the range from 400 vph upto a maximum of 3000 vph only. However the traffic volume on the selected roads (four lane divided) in Chennai during the peak hour varies from 3186 to 9975. The average headway (of all vehicles) at the 10 locations during the full survey period is shown in Figure 1.

To anlyse the data, the Bestfit statistical windows programme was used. For the given data set the software finds the distribution that fits best. More than 25 different distributions are tried to determine the distribution that best fits the data. It performs three standard tests to determine goodness of fit: Chi-square, Anderson – Darling and Kolmogarov – Smirnov.

The peak hour headway (inter arrival time) data of all vehicles were fitted for evaluating the most appropriate distribution. The total data obtained from the field were fitted to get the best distribution. As suggested by Chang and Kim, the headway data set was grouped in appropriate class intervals and the cumulative distribution done. The headway data above 95 % of the cumulative distribution were removed to eliminate long headways. The software was run for each location data set and the distribution which fits the data under both the conditions (with all data and without long headways) was obtained. Table 3 gives the best fit distribution model at all the ten locations – under both conditions. It is found that except for two locations there is variation in the selected distribution model for the headway data.

V. Analysis of Results

It is seen that there is no particular distribution model that fits for all the volume / headway. For the lowest peak hour flow of 3186 vehicles (on Mannarsami Koil Road), the headway was found to follow Inverse Gauss distribution model and for the highest peak hour flow value of 9175 vehicles on Anna Road, it was found to have a Triangular distribution model. The value of the distribution parameters and the salient statistical details of the distributions at all the selected locations are shown in Table 4.

Since there is no single distribution that fits the data at various locations, it was decided to analyse the best three fittings for each location. Table 5 shows the best three distributions that fits the data. It is seen that out of 10 locations, the headway at 7 locations reasonably follow Log Normal 2 distribution and at 5 locations the Inverse Gauss distribution is also found to be acceptable. For location 3, the Inverse gauss distribution is acceptable and for the other two locations (location 5 and 7), the exponential distribution was found to be acceptable. Hence, it is seen that for high volume traffic flow, the following three distributions are found to be acceptable: 1. Log normal 2; 2. Inverse Gauss and 3. Exponential.

Since the volume of flow is very high on most of the road stretches, it was decided to analyse the data for individual category of vehicle. Even though the segregation will not give the real headway of the traffic stream, this analysis will help us to examine the inter arrival time of each category of vehicles in the high volume traffic flow.

Hence, in this study, it was decided to segregate the data for each category of vehicles. The headway for all the seven categories of vehicles (lorry, bus, light commercial vehicles, car, autorickshaws, motorized two wheelers and cycles, including other slow moving vehicles) was extracted independently.

The peak hour inter arrival time data of the 7 data sets (bus, lorry, LCV, car, autorickshaw, motorized two wheeler and cycle) were arranged in ascending order and classified under time interval to draw the cumulative distribution. The data above 95 % of cumulative frequency were discarded to remove long inter arrival time. This data set was tried independently for each of the 10 locations. The data set for Bus, Lorry and LCV's were small when compared to other categories of vehicles. Also, the three categories of vehicles are large sized. Hence it was decided to combine the three categories and fit the data set. The average headway of each category of vehicles at the 10 selected locations is given in Table 6. The best, second best and the third best distributions for each data set separately and for all the ten locations were obtained and are tabulated in Table 7.

Analysis of the seven individual category of vehicles indicate that the Inverse Gauss distribution is found to be the most appropriate type for Bus (7), Lorry (5), Car (9) and Autorickshaws (8) headways. LCV and Cycle headways have equal chances of having either Exponential (8) or Pearson II (9) type of distribution. Triangular distribution was observed in 8 out of 10 locations for Two wheeler headways.

When the headway data of low volume and similar type of vehicles (Bus, Lorry and LCV) were grouped, the Inverse Gauss and Beta General distributions were found to be equally appropriate (8).

Even though all the road sections were four lanes divided, the width of the carriageway varied at each location. It is felt that the lane/carriageway width, volume and the distribution will have to be studied further to examine the reason for a variety of distribution.

VI. Conclusions

It was observed from literature that the headway of vehicles for high volume heterogeneous urban mid blocks have not be examined in detail.

It is found that there is significant variation in the distribution type between the full data and the trimmed data (95% cumulative data after removing small number of long headways).

The headway distribution is random and do not follow a set distribution. 3 different types of distributions, ie, Log Normal 2, Inverse Gauss and Exponential, were found to fit the data at 10 different but similar road stretches.

For high volume traffic flow, segregated flow / headway analysis will be more appropriate, combining small volume of similar vehicle types (Bus/Lorry/LCV).

The distribution of individual vehicle arrival will help to understand the flow / arrival better, where the volume is more and the traffic is heterogeneous and do not follow lane discipline. These micro details can be used effectively for simulation studies for capturing the traffic characteristics better.

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Table 1 : Width and Peak Hour Volume Details at the Survey Locations

Road name	Location No.	Carriageway Width (m)	Peak Hour	Peak Hour Volume in Vehicles	Peak Hour Volume in PCUs.
East Coast Road	1	6.5	8:30 – 9:30	3993	3733
Gandhi Mandapam Road	2	7.5	9:00 – 10:00	5021	4134
Sardar Patel Road	3	8.5	8:45 – 9:45	6252	5090
Anna Road	4	8.9	9:00 – 10:00	9975	8879
Ashoknagar IV Avenue	5	8.5	8:45 – 9:45	4346	3599
Arcot Road	6	7.45	8:45 – 9:45	7079	6091
Medavakam Tank Road	7	7.1	9:00 – 10:00	6370	4929
Periyar Road	8	8.6	9:45 – 10:45	5694	6085
Manarsamy Koil Road	9	6.7	9:00 – 10:00	3186	3360
North Beach Road	10	6.5	9:15 – 10:15	4330	4327