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Empirical Methods of Capacity Estimation of Urban Roads

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In this paper an attempt is made to study the fundamental details of traffic flow and evaluate the capacity of urban mid block section, particularly for a two lane divided cross section. The traffic data at ten locations in Chennai city was collected through video graphic survey. Detailed extraction of traffic headway (inter arrival time), volume and speed were made for every 5 minute time interval, covering both the peak and non peak period. Using the fundamental parameters, capacities of sections were evaluated by three methods, namely Headway method, Observed volume method and Fundamental diagram method.

Detailed analysis of the arrival pattern of vehicles was made and appropriate distribution identified to get the mean headway. The Selected Maxima method assumes that the capacity state is reached during the survey period. As against the normal time slice of 15 minutes, a 5 minute time slice was considered for identifying the peak flow rate. In the third approach, a plot was made between traffic flow in PCU and the speed, to compare the relationship. Since the data was scattered, the enveloping curve technique was adopted, even though the usual pattern of speed flow curve is parabolic.

Keywords: urban roads – heterogeneous traffic – headway – volume – fundamental diagram – empirical methods – capacity.

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The average capacity of a standardized two lane 7m) urban mid block road section was found to be 5649, 5336 and 5146 PCUs by the headway, volume and fundamental diagram methods respectively. It is observed that the capacity values are much higher than the recommended values by Indian Roads Congress (IRC). The reason for this is mainly due to the Passenger Car Equivalent values adopted for different category of vehicles, as recommended by IRC, which requires to be studied in detail.

Keywords: urban roads – heterogeneous traffic – headway – volume – fundamental diagram – empirical methods – capacity.

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I. Introduction

Determination of the capacity of roads is a major issue in the analysis of transportation flow. The capacity of a road is defined as the maximum number of vehicles, per unit time, which can be accommodated under given condition with a reasonable expectation of occurrence.

The capacity and other flow characteristics depend heavily on driver behaviour and the traffic composition. It also depends on the physical and environmental conditions such as the geometric design of facilities, the weather and the lighting. Capacity is only a probabilistic measure. There are variations from time to time and place to place in the maximum number of vehicles that can be accommodated by similar facilities. All the variations cannot be accounted for accurately by the normal determinants of capacity. Since there will be random variation in the number of vehicles that can be accommodated over very short time interval, the capacity is best thought of as the maximum average flow rate that can be sustained.

II. Need and Objective

The literature on road capacity is very diverse. Many developed countries, like USA, UK, Japan, Australia, Sweden, China, and Indonesia have developed capacity manuals. The US highway capacity manual has prepared several graphical and mathematical forms to take care of most of the important parameters affecting the capacity. However, India still does not have a comprehensive capacity manual for our roads. Based on the limited studies carried out so far, the Indian Roads Congress (IRC) has suggested service volume for different categories of urban roads (IRC 106, 1990). An attempt is made in this study to estimate the capacity of urban mid block sections, more particularly, of two lane (divided) roads. In doing so, the basic parameters of flow like headway (inter arrival time), volume and speed are studied and used to estimate the capacity by various direct empirical methods.

III. Literature Review

According to Taylor and others (Taylor, 1998), video techniques have the potential to provide a cheap, quick, easy and accurate method of investigating traffic

systems. Video tapes of traffic counts contain much more information than what the manual recorder can collect.

Isaac and Veeraraghavan (Isaac, 1995) 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 50 % two wheelers):

A study by Chang and Kim (Chang, 2000) 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 was only considered. The authors have concluded that the rational alternative is to take the 95 % cumulative distribution of observed traffic flow, eliminating 5 % of long headways.

Reddy and Issac (Reddy, 1995) 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 was found to be fitting well for vehicle volume less than 720 vph, whereas Erlang distribution fitted well at higher volume level of 1440 to 2880 vph.

Hoogendoorn and Bovy (Hoogendoorn, 1999) have extended the generalised queueing model (GQM) to headway 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 the study, a new approach for modeling mixed- vehicle- type headway distributions was adopted. 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 (Arasan, 2003) 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 (Katti, 1985) 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 Chandra (Chandra, 2001), the exponential and log-normal distributions are not able to describe headway distribution under mixed traffic conditions. The hyperlang distribution was 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 (Al-Ghamdi, 2001) 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 was found to provide a good fit to the observed headway at sites with high traffic flows.

It can be seen that different studies have found various distribution to describe the traffic pattern on roads.

IV. Methodology

There are different methods of estimating the capacity values. Based on the data used and the strategy adopted, the methods are classified as direct empirical and indirect empirical methods (Minderhound, 1997). The basic data that are required for estimation of capacity are roadway width, headway, volume, speed and density. In the direct empirical methods, the observed data are used to estimate the capacity directly. However in the case of indirect methods, the observed data are calibrated and computer programmes developed for estimation of capacity. Sophisticated simulation models have been developed to predict the flow characteristics and to estimate the capacity by many researchers. In the context of Indian urban roads, the understanding of the traffic flow is very limited due to the following reasons; the influence of various types of vehicles sharing the carriageway, the behaviour of drivers, lack of awareness and adherence of traffic rules, non standard lane widths, bad road surface conditions etc. Unless a detailed study is carried out along the lengths and breadths of our country to understand and model the various parameters of traffic flow and other impedance of flow, the simulation model approach may not be accurate to predict the capacity. Since the direct empirical methods are less cost

intensive and can give capacity value to the desired accuracy, it is felt that the direct empirical methods are the more appropriate way of estimating the capacity of roads for Indian conditions.

Depending on the availability of time, manpower and cost, several methods are available to estimate the capacity of roads. The different approach requires various data from just the carriageway width to volume, speed and density of traffic at a particular location. In this attempt the following three approaches were considered to estimate the capacity:

- Headways
- Volume
- Volume and Speed (Fundamental diagram)

a) Headway

Headway is the time separation of vehicles in the traffic stream and is usually measured in fraction of a second. Headways are measured between common points or successive vehicles; time gap are measured from the rear of one vehicle to the front of the next. 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.

For traffic under mixed conditions, exponential, erlang, normal and log-normal distributions for various volume levels have been attempted. In the context of the Indian urban traffic flow conditions, it would be appropriate to consider the full road width, instead of individual lanes for the study since all vehicles are free to use any part of the carriageway. The capacity at a cross section of the road can be estimated with the reciprocal of the mean time headway of the vehicles as given below:

Q= 1 / h (vehicles per second) or Q = 3600 / h (vehicles per hour).

The advantage of this model is that only headways at one cross section of the road at intensity below capacity are required. It is not necessary to wait for a traffic state at about capacity level.

b) Volume

Capacity estimation by this method is made solely with the observed traffic volume. In the observed extreme value method, the estimation of capacity is by using known maximum traffic volumes observed over a period of time. The data to be used for this Selected Maxima method is the hourly traffic volume of flow rates observed in an averaging interval of less than one hour (either 15 mts. or 5 mts. intervals). The basic assumption of this method is that the capacity state of the road is reached during the survey period. The capacity q_c is assumed to be equal to the maximum traffic flow observed during the observation period.

c) Volume and Speed (Fundamental Diagram)

This approach is based on the basic stream flow diagram or Fundamental diagram. The existence of relationship between the two important variables namely traffic volume and harmonic mean speed is used to estimate the capacity. The traffic characteristic, Flow (q) is defined as the number of vehicles passing a specific point or short section in a given period of time, which is expressed as hourly rate (vph). One unique flow parameter is maximum flow or capacity (q_{max}). Speed (u) is defined as the average rate of motion and is expressed in km / hr. In this study, the main focus is on the mid block sections with no obstructions for flow of traffic. Hence the speeds are measured using spot speed technique where the time taken to cover the predetermined length was recorded. The spot speeds are usually higher than the average stream speed, since there are no delays in the short distance of the mid block. From the speed-flow diagram, the flow corresponding to the maximum flow is taken as the Capacity (q_{max}).

V. 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 because of its advantages over the manual and conventional method of collection. 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. 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 survey locations are shown in Figure 1. The video camera was placed at vantage points near the survey locations to collect the data. 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.

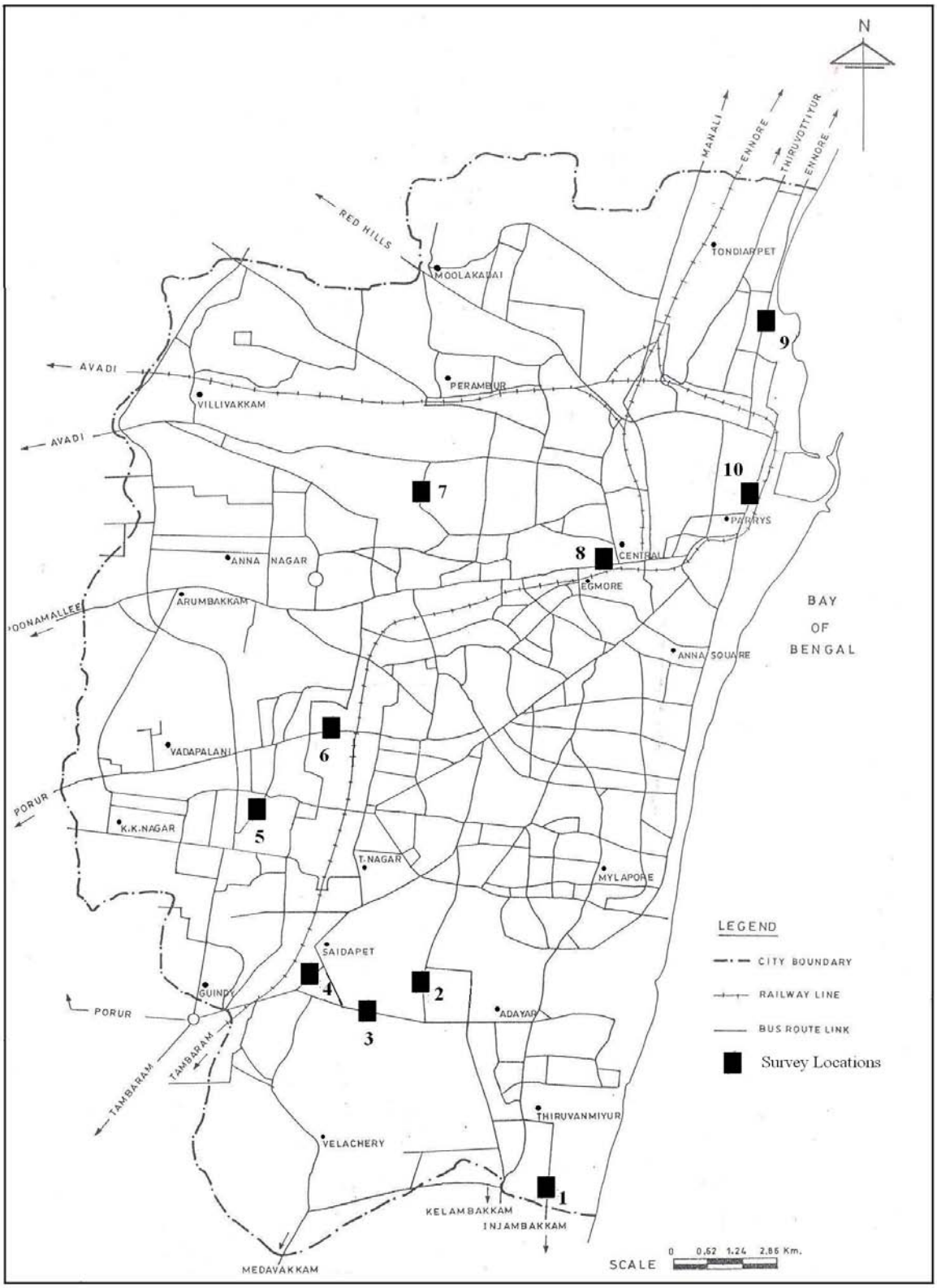

Figure 1 : Location of Points Selected for Video graphic Survey

In addition to the traffic data the physical data like carriageway width, footpath width, and adjoining land use were collected at the survey locations.

VI. 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 (Passenger van, goods carriages 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 for the entire survey period. The data for speed estimation was analysed for sample data, which was not less than 25 percent of the total volume, to get the average speed of the traffic stream and for individual category of vehicle in each five minute time interval.

Capacity estimation by the three different methods mentioned above was carried out to identify the most appropriate method. 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 road stretches are identified by location number 1 to 10. The carriageway width of the road stretch at the survey locations varied from a minimum of 6.5 m at Location 1 and 10 (East coast road and Manarsami koil road) to a maximum of 8.9 m at Location 4 (Anna road). The composition of the traffic stream is also a critical parameter in heterogeneous flow conditions. The traffic compositions at these locations are given in Table 2. Analysis of the peak hour data indicate that the motorized two wheeler is the major component accounting for more than 50 per cent of the total traffic. The percentages of cycles (including other slow moving vehicles) vary from 5.3 percent to 19.03 percent at the selected locations. The combined percentage shares of large sized vehicles (bus, lorry and light commercial vehicles) vary from 1.2 percent to 5.7 percent of the total vehicles. The observed number of categorized vehicles was converted into equivalent PCU by adopting the values recommended by Indian Roads Congress. The peak hour traffic was observed to be lowest at Location no. 9 (Manarsami koil road) with 3360 PCU and highest at Location no. 4 (Anna road) with 8879 PCU.

Table 1 : Effective Carriageway Width and Peak Hour Volume Details

Road name	Loc No.	Road Width (m)	Peak Hour	Peak Hour Volume in Vehicles	Peak Hour Volume in PCU
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

Source : Survey Analysis

Table 2 : Composition of Traffic in Per Cent (Peak Hour)

Loc. No.	Bus	Lorry	LCV	Car	Auto	Two wheeler	Cycle	Total
1	0.88	0.68	2.05	16.65	12.10	52.17	15.48	100
2	0.30	0.34	0.90	19.92	7.37	63.83	7.35	100
3	1.63	0.74	1.62	13.88	7.17	55.93	19.03	100
4	1.35	0.67	1.80	12.99	10.39	67.49	5.30	100
5	0.39	0.39	1.73	14.36	8.58	59.69	14.86	100
6	1.10	0.21	1.40	11.99	10.41	58.57	16.32	100
7	0.53	0.13	0.53	6.55	8.48	66.26	17.52	100
8	1.33	1.02	2.28	16.84	20.06	51.86	6.60	100
9	1.54	1.07	1.85	4.65	21.72	59.95	9.23	100
10	2.79	1.39	1.57	6.81	15.27	63.65	8.43	100

VII. Capacity Estimation

a) Headway

Most of the studies done on analysis of headway distribution have examined vehicular flow in the range from 400 vph up to a maximum of 3000 vph only. However the traffic volume on the selected roads (two 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 covering both the peak and off peak period is shown in Figure 2. It is evident that the headway is minimum during the peak period.

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 20 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. Also, 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 distribution which fits the data under both the conditions (with all data and without long headways) is shown in Table 3. It is seen that except for two locations, there is change in the distribution model selected in the case of data set without long headways.

It is seen that no particular distribution fits for all the ten headway data sets. The distribution models at all the selected locations with the estimated values for the parameters are shown in Table 4. For the lowest peak hour flow of 3186 vehicles (Location No. 9 - 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 (Location No. 4), it was found to have a Triangular distribution model.

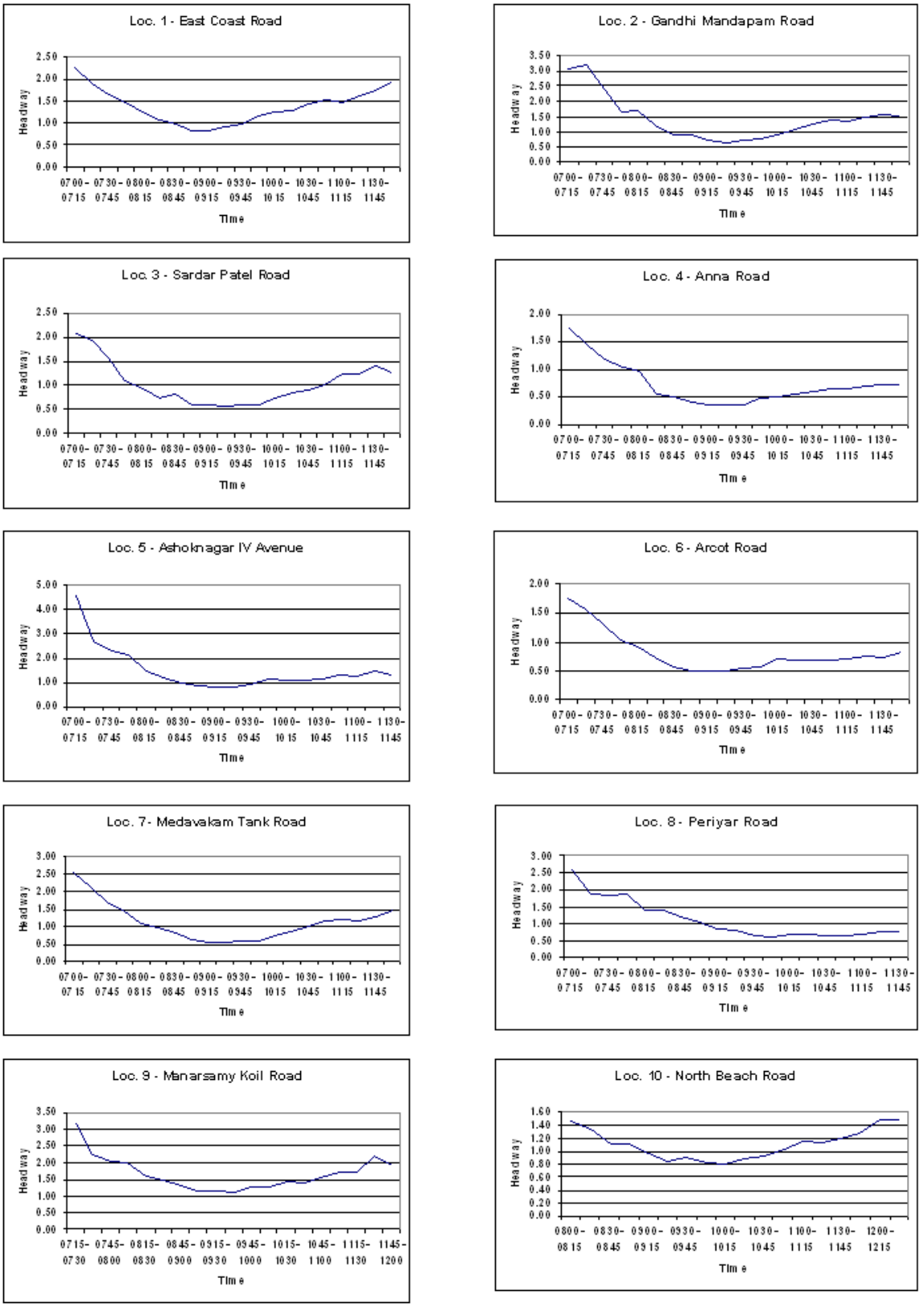

Figure 2 : Average Headway of Vehicles at the survey locations

Table 3 : Headway Model With and Without Long Headway

Loc. No.	With all Headway Data	Without Long Headway Data
1	Gamma	Weibull
2	Pearson 5	Pearson 5
3	Log Log	Inverse Gauss
4	Pareta 2	Triangular
5	Pearson 5	Log Normal 2
6	Exponential	Weibull
7	Inverse Gauss	Exponential
8	Log Normal 2	Beta General
9	Inverse Gauss	Inverse Gauss
10	Log Normal 2	Pareto 2

Source : Survey analysis

Table 4 : Statistical Details of Best Headway Model at all Locations

Loc. No.	Best model	Mean	Standard. Deviation.	Equation
1	Weibull	0.717	0.597	(1.2092, 0.7654)
2	Pearson 5	0.576	0.567	(4.9937, 3.9207)
3	Inverse Gauss	0.425	0.374	(0.5357, 1.0986)
4	Triangular	0.351	0.248	(0,0, 1.0542)
5	Log Normal 2	0.814	0.877	(-0.4256, 0.8117)
6	Weibull	0.417	0.363	(1.1641, 0.4438)
7	Exponential	0.455	0.454	0.4549
8	Beta General	0.481	0.432	(0.7113, 2.3117)
9	Inverse Gauss	1.071	1.281	(1.206, 1.0686)
10	Pareto 2	0.615	0.724	(3.7887, 7.1570)

Since there is no single distribution model 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 distribution models that fits the data. It is seen that out of 10 locations, the headway at 7 locations reasonably follow Log Normal 2 distribution model and at 5 locations the Inverse Gauss distribution model was found to be acceptable. For the two locations (Location No. 7 and 8), the exponential distribution model was found to be acceptable. Hence, it is inferred that for high volume mid block traffic flows, the following three distribution models are acceptable: 1. Log normal-2; 2. Inverse Gauss and 3. Exponential.

Table 5 : Three Best Headway Models (without long headways)

Loc. No.	Best	Second best	Third best
1	Weibull	Beta General	Inverse Gauss
2	Pearson 5	Log Normal 2	Inverse Gauss
3	Inverse Gauss	Log Normal 2	Exponential
4	Triangular	Extreme value	Log normal 2
5	Log Normal 2	Inverse Gauss	Erlang
6	Weibull	Log Normal 2	Inverse Gauss
7	Exponential	Pareto 2	Pearson 5
8	Beta General	Weibull	Exponential
9	Inverse Gauss	Log Normal 2	Pareto 2
10	Pareto 2	Beta General	Log normal 2

Source : Survey analysis

Using the identified distributions, the estimated mean headway of all the three distribution models and the average of the mean at all the ten locations are given in Table 6. The average headway varies from 0.317 seconds at Location No. 4 (Anna Road) to 1.074 seconds at Location No. 9 (Manarsami Koil Road). The estimated total capacity of each road section using the average mean value is given in column 4. Based on the composition of the traffic at each location, the number of vehicles has been converted into equivalent PCU. Since the width of the carriageway is varying, the capacity is normalized for a standard 7 m two lane width using the following equation:

$$NC = \frac{TC * SW}{CW}$$

Where NC – Normalised capacity; TC - Total Capacity
CW - Carriageway width of the section (m)
SW - Standard width of 7 m.

The normalized value for the standard two lane carriageway width (7 m) is shown in the last column. The estimated capacity varies from a minimum of 2979 PCU to 8340 PCU. Based on the observed headway, the average capacity of a two lane urban road was estimated to be 5649 PCU.

Table 6 : Capacity Estimation by Headway Model

Loc. No.	Mean Headway			Average of Mean Headway	Total Capacity in Vehicles	Total Capacity in PCU	Normalised Capacity in PCU (7 m)
	I	II	III				
1	0.717	0.719	0.717	0.718	5016	4716	5079
2	0.425	0.428	0.425	0.426	8451	6881	5666
3	0.576	0.575	0.568	0.573	6283	5167	4822
4	0.351	0.296	0.305	0.317	11345	10603	8340
5	0.814	0.802	0.802	0.806	4467	3617	2979
6	0.417	0.424	0.419	0.420	8571	7691	7227
7	0.455	0.455	0.459	0.456	7889	6104	6018
8	0.481	0.481	0.482	0.481	7479	7992	6505
9	1.071	1.082	1.069	1.074	3352	3522	3679
10	0.615	0.613	0.656	0.628	5732	5729	6170

Source : Survey analysis. *All headway values in seconds*

b) Volume

The peak hour data was further analysed to estimate the capacity flow conditions. The flow in each 5 minute time interval for each category of vehicles were extracted and the equivalent PCU calculated based on the recommended values by IRC. The maximum flow in any 5 minute interval was identified. This peak flow rate is multiplied by a factor 12 to estimate the capacity flow per hour. The normalized capacity value for a standard width of 7 m was also estimated. Similar exercise for other locations was done and the details are given in Table 7. The maximum and minimum capacity values obtained by this method were 8258 PCU and 3310 PCU respectively. The average capacity by this approach was found to be 5336 PCU.

Alternatively, the average of three highest values was considered while estimating the capacity. The three maximum flows in 5 minute interval at the location were identified. The peak flow rate (maximum flow in 15 minutes) is then multiplied by 4 to get the peak flow per hour. The normalized value for the standard two lane carriageway width (7m) is then calculated. The details at all the ten locations are given in Table 8. By this method, the average capacity was found to be 5075 PCU.

Table 7 : Capacity Estimation by "Selected Maxima" Model (5 min. time slice)

Location No.	Peak Hour Volume in PCU	Max Flow in 5 mts	Total Capacity in PCU	Normalised Capacity in PCU (7m)
1	3733	346	4152	4471
2	4134	466	5592	4605
3	5090	432	5184	4838
4	8879	875	10500	8258
5	3599	335	4020	3310
6	6091	574	6888	6472
7	6085	574	6888	6791
8	4929	515	6180	5030
9	3360	355	4260	4451
10	4327	397	4764	5130

Source : Survey analysis

Table 8 : Capacity Estimation by "Selected Maxima" Model (15 min. time slice)

Location No.	Peak Hour Volume in PCUs	Max Flow in 5 min.			Max. Flow in 15 min.	Total Capacity in PCU	Normalised Capacity in PCU (7m)
		I	II	III			
1	3733	346	346	341	1033	4132	4450
2	4134	466	460	425	1351	5404	4450
3	5090	432	392	367	1191	4764	4446
4	8879	875	775	759	2409	9636	7579
5	3599	335	320	320	975	3900	3212
6	6091	574	549	543	1666	6664	6261
7	6085	574	553	546	1673	6692	6598
8	4929	515	458	453	1426	5704	4643
9	3360	355	309	300	964	3856	4029
10	4327	397	390	390	1179	4716	5079

Source : Survey analysis

There is a drop of nearly 5 per cent in the capacity when the time slice for the peak flow rate was increased from 5 minutes to 15 minutes.

c) Volume & Speed

The volume (in PCU) for each 5 minute block was converted into hourly flow. The speed for each category of vehicles was calculated based on the time taken to move over a fixed length of the carriageway. The speed of Fast moving vehicles alone was considered for analysis since the number of slow moving vehicles is less and the difference in speeds is very large. The weighted average stream speed is calculated taking into account the speed and the number of vehicles in each category during each time interval.

The traffic flow in PCU corresponding to the average speed was plotted to find the relationship between the two. Since the data was very scattered, no regular relationship was fitting. The Enveloping curve technique developed at CRRI, New Delhi and also used by Dr. Satish Chandra was used to determine the capacity of the road. Even though the usual pattern of the speed flow curve is parabolic, for reasons stated earlier, a curve passing through the origin and bounding all the points was drawn for each location. The speed flow graphs for all the ten locations using the enveloping curve method were made and is depicted in Figure 3 to 12. The maximum flow, which is taken as the capacity flow and the normalised value for the standard two lane width, for each location is given in Table 9. By this method, the average capacity was found to be 5146 PCU.

Table 9 : Capacity Estimation by Fundamental Diagram Method

Location No.	Effective Carriageway Width (m)	Total Capacity in PCU	Normalised Capacity in PCU (7m)
1	6.5	3875	4173
2	7.5	4820	4499
3	8.5	5750	4735
4	8.9	10400	8180
5	8.5	3750	3088
6	7.45	6430	6042
7	7.1	5570	5492
8	8.6	6880	5600
9	6.7	4180	4367
10	6.5	4910	5288

Source : Survey analysis

The average capacity of two lane divided (two way) urban mid block was estimated to be 5649, 5075, and 5146 PCU by Headway, Volume and Fundamental diagram methods respectively.

Figure 3. Speed Flow Curve – East Coast Road

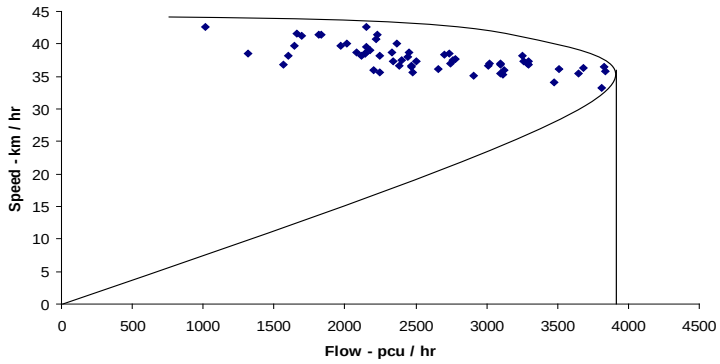

Figure 3 : Speed Flow Curve – East Coast Road

Figure 4. Speed Flow Curve – Gandhi Mandapam Road

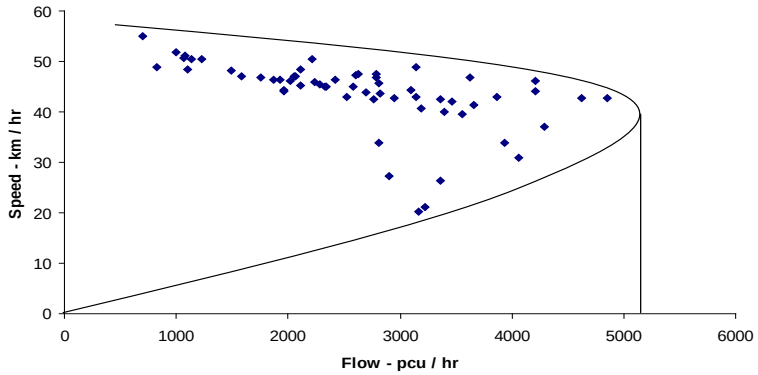

Figure 4 : Speed Flow Curve – Gandhi Mandapam Road

Figure 5. Speed Flow Curve – Sardar Patal Road

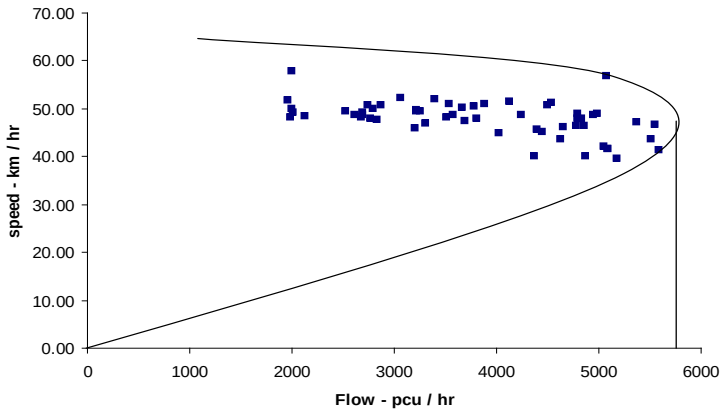

Figure 5 : Speed Flow Curve – Sardar Patal Road

Figure 6. Speed Flow Curve - Anna Road

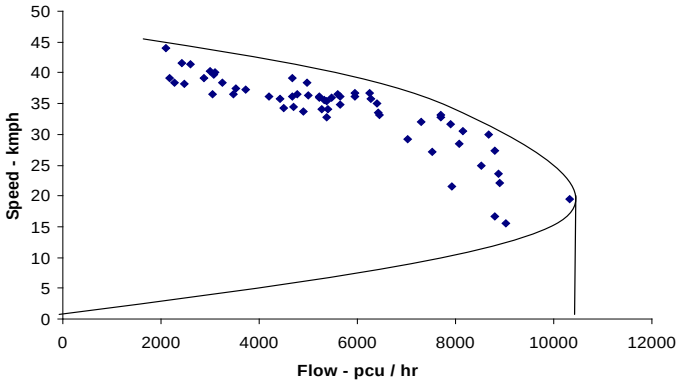

Figure 6 : Speed Flow Curve – Anna Road

Figure 7. Speed Flow Curve – Ashoknagar IV Avenue

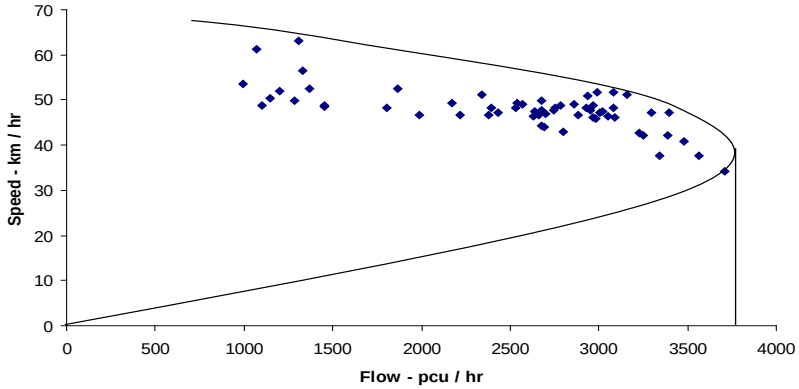

Figure 7 : Speed Flow Curve – Anna Road

Figure 8. Speed Flow Curve - Arcot Road

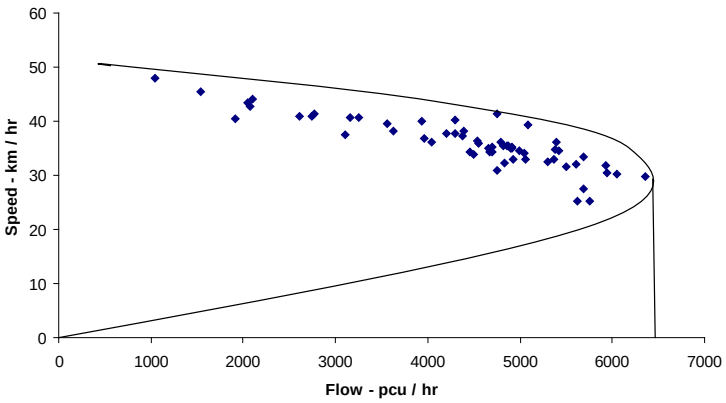

Figure 8 : Speed Flow Curve – Arcot Road

Figure 9. Speed Flow Curve – Medavakam Tank Road

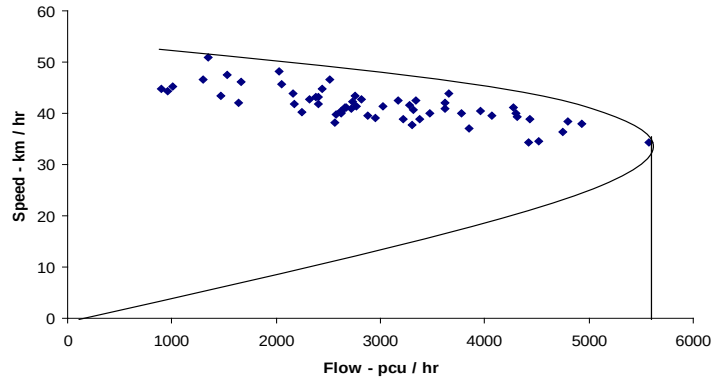

Figure 9 : Speed Flow Curve – Medavakam Tank Road

Figure 10. Speed Flow Curve – Periyar Road

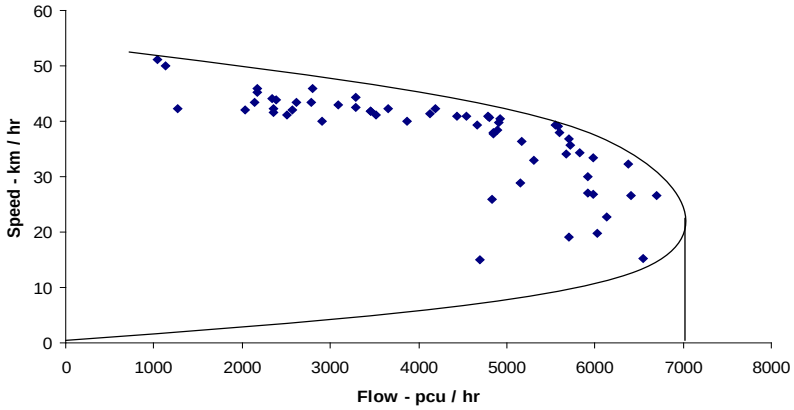

Figure 10 : Speed Flow Curve – Periyar Road

Figure 11. Speed Flow Curve - Manarsami Koil Road

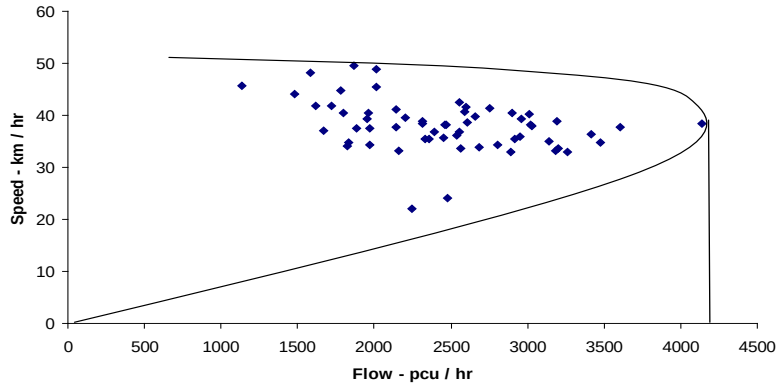

Figure 11 : Speed Flow Curve – Manarsam I Koll Road

Figure 12. Speed Flow Curve - North Beach Road

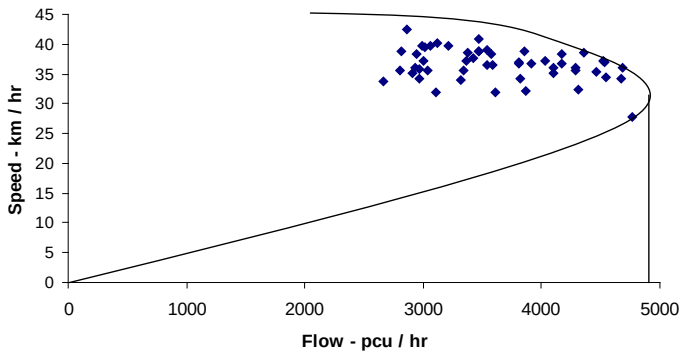

Figure 12 : Speed Flow Curve – North Beach Road

VIII. Observations and Conclusions

It is clear from literature that Capacity of a facility is only an estimate and is not a constant. It varies with time, location, composition and other local factors. The major elements of traffic flow are the Vehicle, Driver and Way. Since the roads in India are not of standard dimensions and there is lack of lane discipline with several types of vehicles sharing the same way, it would be appropriate to adopt direct empirical methods for capacity estimation. With various factors influencing the value of capacity, the Direct empirical methods using the observed fundamental traffic characteristics like Headway (inter arrival time), volume and speed are relevant for capacity estimation.

The distribution of Headway (inter arrival time) of vehicles were found to vary from location to location. However, when three best distributions were considered, Log Normal 2, Inverse Gauss and Exponential distributions were found to represent the traffic data. The average capacity estimated by this method was found to be 5649 PCU.

The estimated capacity by the Selected Maxima method with a time slice of 5 minutes was 5336 PCU. However when three maximum flows in each 5 minute interval were taken into consideration, the average capacity was estimated as 5075 PCU. There is a drop of nearly five per cent in capacity when the time interval was increased from 5 to 15 minutes.

Even though the pattern of the speed flow curve is parabolic in nature, the data obtained from the field were found to be scattered. Using the enveloping curve technique, the average capacity flow for a two-lane two-way mid-block was estimated as 5146 PCU.

As reported in literature, the capacity estimate made using the headway model was observed to be the highest. Since the fundamental diagram approach has the speed factor also in the capacity estimation, this method will indicate the capacity flow with the known stream speed. As the fundamental parameters of traffic flow are headway, volume and speed, it is felt that for capacity estimation, all the three methods need to be done and compared for arriving at the best value.

The estimated capacity value by all the three methods was found to be much higher than the IRC recommended value for two-lane two-way divided urban roads. The reason for the higher capacity value could be attributed to the drastic change in the flow characteristics and the driver behaviour. The higher volume on the road has made the drivers to be more aggressive. The lateral and longitudinal gaps between vehicles on the urban roads are also lesser now, than the recommended values. The recommended PCE values of IRC, especially for autorickshaws (2 – for more than 10% of the total traffic) and for motorized two wheelers (0.75 – for more than 10% of the total traffic) appear to be on the higher side. Vehicles are also observed to traverse with reduced headway and side clearances because of the increase in vehicular volume. Even though several attempts have been made to estimate the Passenger Car Unit (PCU) value for various categories of vehicles, there are no acceptable values for a given condition and it requires further research.

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