

## SPEED- FLOW STUDIES AND CAPACITY ANALYSIS OF MULTILANE ROADS

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### ABSTRACT

India has a road network of over 54,72,144 kms (3,400,233 mi) as on 31 March 2015, the second largest road network in the world. At 1.66 km of roads per square km of land, the quantitative density of India's road network is higher than that of Japan (0.91) and the United States (0.67), and far higher than that of China (0.46), Brazil (0.18) and Russia (0.08). However, qualitatively India's roads are a mix of modern highways and narrow, unpaved roads, and are being improved. As on 31 March 2015, 61.05% of Indian roads were paved. Adjusted for its large population, India has less than 3.8 kms of roads per 1000 people, including all its paved and unpaved roads. In terms of quality, all season, 4 or more lane highways. India has less than 0.07 kms of highways per 1000 people, as of 2010.

**Keywords:** Indian Roads Congress, traffic stream, modern highways

### 1. INTRODUCTION

Indian Roads Congress (IRC) has evolved guidelines on capacity of rural roads. These guidelines are based on experience of developed countries and studies done in India. IRC: 64-1990 provides the 'Guidelines for Capacity of Roads in Rural Areas'. The following points from guidelines are mentioned below.

Speed is the rate of motion of individual vehicle or of a traffic stream expressed in km/hr. two types of speed measurements are commonly used in traffic flow analysis.

- i. Time mean speed and
- ii. Space mean speed

For the purpose of these guidelines, the speed measure used is "Space mean speed".

Time mean speed is the mean speed of vehicles observed at a point on the road over a period of time. It is the mean spot speed. Space mean speed is the mean speed of vehicles in a traffic stream at any instant of time over a certain length (space) of road. In other words, this is average speed based on the average travel time of vehicles to traverse a known segment of roadway. It is slightly less in value than the time mean speed.

#### Idealized Speed-flow Relationships

The idealized relationship between speed, volume and density is expressed in the three basic diagrams which are collectively known as the Fundamental Diagram of Traffic Flow. It will be seen that the speed-density relationship is a straight line, having maximum speed (free speed) when traffic is low and having zero speed where vehicles are jammed. The speed-volume relationship is a parabola, having maximum volume at a value of speed equal to half the free speed. The density-volume relationship is a parabola, having a maximum volume at a value of density equal to half the jamming density. The fundamental equation relating speed, volume and density is

$V = DS$ , Where

$V$  = Volume,  $D$  = Density,  $S$  = Speed

The maximum volume that can be accommodated on the road is considered to be the road capacity. From the idealized relationship, it is seen that the maximum volume occurs at half the free speed and half the jamming density, meaning thereby that:  $V_{max} = \frac{S}{2} \times \frac{D}{2} = \frac{SD}{4}$ .

#### Capacity and Design Service Volume

From the viewpoint of smooth traffic flow, it is not advisable to design the width of road pavement for a traffic volume equal to its capacity which is available at LOS E. At this level, the speeds are low (typically half the free speed) and freedom to maneuver within the traffic stream is extremely restricted. Besides, at this level, even a small increase in volume would lead to forced flow situation and breakdowns within the traffic stream. Even the flow conditions at LOS C and D involve significant vehicle interaction leading to lower level of comfort and convenience. In contrast, Level of Service B represents a stable flow zone which affords reasonable freedom to drivers in terms of speed selection and maneuvers within the traffic stream. Under normal circumstances, use of LOS B is considered

adequate for the design of rural highways. At this level, volume of traffic will be around 0.5 times the maximum capacity and this is taken as the "design service volume" for the purpose of adopting design values. It is recommended that on major arterial routes LOS B should be adopted for design purposes. On other roads under exceptional circumstances, LOS C could also be adopted for design. Under these conditions, traffic will experience congestion and inconvenience during some of the peak hours which may be acceptable. This is a planning decision which should be taken in each case specifically after carefully weighing all the related factors. For LOS C, design service volumes can be taken as 40 per cent higher than those for LOS B given in subsequent paragraphs. In the context of rural highways, it is usual to adopt daily traffic volumes for design instead of hourly volumes. Therefore, the hourly flows need to be converted to daily values on the basis of observed or anticipated hourly pattern of traffic during the 24 hour day. Currently, the peak hour factor on trunk routes in the country is around 8-10 per cent of the AADT and the capacity figures recommended in the guidelines have been based on this.

## 2. OBJECTIVES OF THE STUDY

The study under consideration aims at collecting the speed-flow data of the selected stretch of NH-1 and SH-6 which is 6-lane and 4-lane divided road respectively.

The main objectives of the study include:

- To collect the speed-flow data of the identified roads.
- To determine the traffic composition of the roads.
- To study the speed variation among different vehicles.
- To study the speed frequency curves of the traffic and determine design speed and safe speed for the roads.
- To evaluate the speed spread ratio on both roads to determine the conditions of normality of speed distribution curves.
- To evaluate the capacity of the roads and compare it with other notable standards/works.

## SCOPE OF STUDY

In the present study, the collected speed-flow data pertain to National highway 1 and State highway 6. The selected stretches of the roads represent the midblock sections away from the city areas. NH-1 (new name NH-44, Pipli-Karnal Section) is a six lane divided road with paved shoulders whereas SH-6 (Kurukshetra-Pehowa Section) is a four lane divided road with earthen shoulders. The results of the study are applicable to the selected stretches of the roads. However, the methodology of the study and results obtained can be applied to any other road having similar roadway and traffic conditions.

## 3. LITERATURE REVIEW

Speed-flow study can be used to determine the capacity of the road. Capacity analysis is fundamental to planning, design and operation of roads, and provides, among other things, the basis for determining the carriageway width to be provided at any point in a road network with respect to volume and composition of traffic. Moreover, it is a valuable tool for evaluation of the investments needed for future road construction and improvements, and for working out priorities between the competing projects.

Katti et al (1986) developed speed models based on traffic data collected on sub-urban sections of three cities in India. The average speed of fast vehicles varied from 37.8 kmph to 51.5 kmph and for slow vehicles the variation was observed from 10.75 kmph to 15.83 kmph. Speed dispersion was high for fast vehicles and low for bicycles. Leong(1968) and McLean (1978) found that, for lightly trafficked two-lane roads where most vehicles are traveling freely, car speeds measured in time are approximately normally distributed with coefficient of variation ranging from about 0.11 to 0.18. Leong studied speed and capacity at 31 sites in New South Wales between the periods of 1963 to 1973. This data was examined using multiple regression model and one of the outcome of the study was that with the increase in width of the pavement, shoulder and sight distance, there is an increase in the free speed. Al-Ghamdi(1998) collected the spot speed data on the roads of Riyadh and found that 85th speed percentile from regression modeling gives much better estimates than those from the normal approximation model, while as on the other hand approximately 90% of the motorists were exceeding the speed limits, indicating that much more speed limit enforcement is needed. Peerzada Mosir Shah et al (2016) demonstrate the effect of traffic composition on the speed distribution curve on a section of multilane divided urban highway under mixed traffic conditions. It depicts that the speed data may or may not follow the normal distribution curve as there is dependence of the variation and proportion of slower vehicles like 3-wheelers, cycles and cycle rickshaws in the traffic stream. Greater the percentage of slow moving vehicles such as auto rickshaw and cycles, lower is the possibility that speed data follows the normal distribution curve.

## CAPACITY OF RURAL ROADS

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In the context of rural highways, it is usual to adopt daily traffic volumes for design instead of hourly volumes. Therefore, the hourly flows need to be converted to daily values on the basis of observed or anticipated hourly pattern of traffic during the 24 hour day. Currently, the peak hour factor on trunk routes in the country is around 8-10 per cent of the AADT and the capacity figures recommended in the guidelines have been based on this.

The design service volume that should be considered for design/improvement of a road facility should be the expected volume at the end of the design life. This can be computed by projecting the present volume at an appropriate traffic growth rate. The traffic growth rate should be established after careful study of past trends and potential for future growth of the traffic. IRC recommends design service volume for non-urban roads in plain terrain.

### EQUIVALENCY FACTORS

Passenger Car Unit (PCU) is a metric used in Transportation Engineering, to assess traffic-flow rate on a highway. A Passenger Car Unit is a measure of the impact that a mode of transport has on traffic variables (such as headway, speed, density) compared to a single standard passenger car. This is also known as passenger car equivalent.

#### SPEED SPREAD RATIO

Speed data of a traffic stream usually follows the normal distribution when the traffic is homogeneous, but in case of heterogeneous it may or may not follow the normal distribution. In case of heterogeneous traffic, it deviates from the normal curve. The mathematical study of the observed data makes it possible to understand the speed characteristics. In many developing countries such as India, Bangladesh, Pakistan the traffic is heterogeneous. In all these developing countries within same group of vehicle such as Buses we have 4-6 different sizes of buses on roads with different characteristics. From speed spread ratio (Dey et al, 2006), we can check the spread of speed for different sections and thereafter analyzing the speed-flow curve if it follows the normal distribution pattern.

$$SSR = (V_{85} - V_{50}) / (V_{50} - V_{15})$$

#### 4. METHODOLOGY

In the present study, volume and speed-flow data was collected for evaluation of capacity of 4 lane and 6 lane road sections and to study speed-flow characteristics for the selected stretches of 4 lane and 6 lane roads. The first set of data for speed flow studies was collected at mid-block section of NH-1 (Pipli-Karnal road) which is six lane divided (three lanes on either side) road in Kurukshetra district and second set of data was collected at mid-block section of SH-6 (Kurukshetra- Pehowa road) which is four lane divided (two lanes on either side) road in kurukshetra district. The carriageway width for 6-lane road section was 10.5m either side with paved shoulder of 1.5m width and the width of the median was 4.4m. The carriageway width for 4 lane road was 7.0m either side with paved shoulder of 1.5m width and the width of the median was 2.0m.

#### SITE SELECTION CRITERIA

The road sections chosen for the present study are on NH-1 (six-lane) and SH-6 (four-lane) based on the following criteria:

- a) The road sections should be straight, without any intersection and turning moments
- b) The site should not have any obstruction to sight distance.
- c) The study area should have proper working space of the teams.
- d) Drivers should not be distracted by the working teams while driving.
- e) Study area should be safe for working of teams.

#### 5. METHOD OF DATA COLLECTION

Manual counting method was adopted for this study. In this method, traffic data is recorded by a team of enumerators (traffic persons) which is deputed to record traffic count on the prescribed record sheets (tally sheets) in a specific period of time. The main advantage of using this method is that field team can record the type and direction of the vehicles. However it is not possible to record the traffic volume data for all the 24 hours of the day and of all the days round the year using manual method. For the present study, the survey was carried out for a period of 3 hours on a typical day of the week for each section. In addition to the traffic data, the format by making tally marks. One observer noted down the number and type of vehicles on one side of the road. For speed study, a 30 m stretch was selected on the identified sections of NH-1 and SH-6 and time taken by the vehicles to cross this section was noted down. Two members were used for this purpose, one for controlling the stop watch and another for noting down the time observed in the stop watch to pass the 30m stretch of road by different vehicles on a pre-prepared sheet. The accuracy of the stop watch was 0.01 sec.

Traffic Flow data as collected on 6-lane section of NH-1. Similarly, traffic flow data was collected on SH-6 for intervals of 5 minutes and for each type of vehicles like cars, two wheelers, three wheelers, L.C.V, HCV, multi axle trucks, non-motorized traffic like bullock cart, hand cart etc.

The traffic on the selected stretch was of heterogeneous nature with a prominent percentage of cars. Traffic on the selected stretch of NH-1 consists of 60% Cars, 20% Trucks, 5% Buses, 13% two wheelers and rest other vehicles. In terms of PCUs the traffic consists of 40% cars, 43% Trucks, 10% Buses, 4% two wheelers and rest other vehicles. Table 4.1 gives the composition of traffic on NH-1 in terms of %vehicles and %PCUs. The equivalency factors are used for conversion of traffic into PCU.

Non Commercial vehicles in PCUs on NH-1, the traffic consists of about 25% commercial vehicles and rest non-commercial vehicles on NH-1 and in terms of PCU approximately 54.5% are commercial vehicles and 45.5% vehicles are non-commercial. A commercial vehicle is a vehicle that is licensed to be used for the transportation of goods or material or paid passengers.

Slow Moving Vehicles (SMV), 0.04



Fast Moving Vehicles (EMV), 99.96

Slow Moving Vehicles (SMV), 0.01

Fat Moving Vehicle (FMV), 90.09

The traffic consists of 99.96% fast moving vehicles and rest slow moving vehicles on NH-1. Slow moving vehicles mainly consist of cycle, cycle rickshaw and animal drawn vehicles. In terms of PCU, traffic consists of 99.99% of fast moving vehicles for H-1 and 0.01% of slow moving vehicles.

The traffic consists of about 13% vulnerable road users and 86% non-vulnerable road users. A vulnerable road user is that user who is more prone to the road accidents. In terms of PCU, vulnerable road users (VRU) are about 4.5% and remaining are the non-vulnerable road users,

Composition of Traffic on SH-6

Traffic in terms of vehicles on the selected stretch of SH-6 consists of 33% Cars, 2% Trucks, 1.6% Buses, 50% two wheelers and rest other vehicles. The composition of traffic on SH-6 in terms of vehicles and %PCUs. The equivalency factors are used for conversion of traffic into PCU as per 2.3.

Slow Moving Vehicles (SMV), 4.56

Fast Moving Vehicles (FMV), 95.44

Slow Moving Vehicles (SMV), 3.87

Fast Moving Vehicles (MV), 96.13

NH-1

1. NH-1 (New name NH-44) is a national highway which runs from New Delhi to Atari and is of approximately 456 kms and the section under study is a 6-Lane section.

2. Major component of traffic on NH-1 is of Cars in terms of vehicles, and in terms of PCU approximately 40% cars and 40% trucks constitute the traffic.

3. Negligible percentage of slow moving vehicles on NH-1.

4. In terms of vehicles, about 25% traffic is constituted by commercial vehicles. In terms of PCU, composition of commercial vehicles is about 54%.

5. In terms of vehicles, 13% of the traffic is of vulnerable road users and in terms of PCU, the proportion of vulnerable road users is about 4.5% of the traffic.

SH-6

1. SH-6 is a state highway which runs from Saharanpur to Pehowa and consists of approximately 109 kms road length. The road section under study is 4-lane section.

2. On SH-6, major component of traffic in terms of vehicles is 2-wheelers and in terms of PCUs, 40% of the traffic is contributed by cars and about 30% of the traffic is contributed by 2-wheelers.

3. 4.56% traffic consists of slow moving vehicles which is approximately 3.87% in terms of PCU.

4. In terms of vehicles, approximately 4% traffic is contributed by commercial vehicles on SH-6 and in terms of PCU, only 18% of the traffic is composed of commercial vehicles.

5. In terms of vehicles, 54% of the traffic is of vulnerable road users which is major component of traffic. Thus accidents are more prone to occur on this road as compared to NH-1. To prevent accidents, relatively lower speed can be implied on this section.

PEAK HOUR FACTOR

Peak hour factor is defined as the ratio of the peak hour traffic volume to the average daily traffic (ADT). 30% highest hourly traffic volume is taken as the peak hour volume. In absence of the AADT data, the peak hour factor of 10% is adopted for the calculation of the maximum average daily traffic as per IRC:64-1990.

COMPOSITE PCU

Composite PCU is a tool which can be very beneficial for conversion of traffic into PCUs in a simplified manner. Composite PCU value evaluated for NH-1 is found out to be 1.48 and that of SH-6 comes out to be 0.84. Such difference in composite PCU for both cases indicates high percentage of heavy vehicles on NH-1. Physical data like carriageway width, shoulder width and median width were measured at the survey location. A blank tally sheet is provided in Appendix A which is used to record traffic data in the field.

For speed-flow studies, the speed of the vehicles is evaluated using the 30m section of selected lanes and stopwatch was used to record the time lapsed by the vehicle to cover the 30m distance.

## 6. COLLECTION OF SPEED-FLOW DATA

Volume is the actual number of vehicles observed or predicted to be passing a point in a given time interval. The rate of flow represents the number of vehicles passing a point during a time less than 1 hour, but expressed as an equivalent hourly rate. Time intervals ranging from about 2 minute to upto one hour are used to measure capacity of facilities and to determine daily peaking patterns (James, 1998). For the purpose of highway capacity analysis, time interval is taken to be around 5 minute (Papacostas, 1990). In road user cost study (CRRI, 1982), a time interval of 5 minute traffic count was used to derive speed-flow relationships. Kadiyali et al...

(1991) also used a 5 minute count to evolve speed-flow relationship and to determine Capacity of road. Time intervals in this range are used because they reduce random variation without unduly obscuring repetitive peaking patterns.

In the present study, a 5 minute time interval was taken to determine the equivalent hourly traffic flow rate. Accordingly, speed-flow data was collected in terms of 5 minute intervals for 3 hours duration between 09:45 am to 12:45 pm at mid-block section of NH-1 (Pipli-Karnal Section) which is six lane divided (three lanes on either side) road. Similarly, the data for speed-flow study also collected at mid-block section of SH-6 which is a four-lane divided highway (two lanes on either side). The survey on SH-6 was carried out for a period of three hours between 09:30 am to 12:30 pm. All the data were collected manually for one side of the median and multiplied by 2 for both the directions. In the procedure of data collection, the number and type of vehicles and their respective speed were noted down in each 5 minute interval during the total duration of the study. 5 minute traffic count is converted to the equivalent hourly flow rate by multiplying the number of vehicles with 12. The number and type of vehicles was marked on a pre-prepared.

## 7. CONCLUSIONS

The study presented in the dissertation has been conducted to collect the speed-flow data, to determine the traffic composition, to study the speed variation in different vehicles and speed frequency curves, to determine design speed and safe speed on selected stretches of NH-1 and SH-6, to evaluate the speed spread ratio and to evaluate the capacity of NH-1 and SH-6.

The following main conclusions are drawn from the work:

### 1. Traffic Composition

- a) Traffic on the selected stretch of NH-1 consists of 60% Cars, 20% Trucks, 5% Buses, 13% two wheelers and rest other vehicles. In terms of PCUs the traffic consists of 41% cars, 43% Trucks, 10% Buses, 4% two wheelers and rest other vehicles.
- b) Traffic on the selected stretch of SH-6 consists of 33% Cars, 2% Trucks, 1.6% Buses, 50% two wheelers and rest other vehicles. In terms of PCUs the traffic consists of 40% cars, 8% Trucks, 6% Buses, 29% two wheelers and rest other vehicles.
- c) The traffic consists of about 25% commercial vehicles and rest non-commercial vehicles on NH-1. In terms of PCU approximately 54.5% are commercial vehicles and 45.5% vehicles are non-commercial.
- d) The traffic consists of about 4.78% commercial vehicles and rest non-commercial vehicles on SH-6. In terms of PCU approximately 18% are commercial vehicles and 81% vehicles are non-commercial.
- e) The traffic consists of 99.96% fast moving vehicles and rest slow moving vehicles on NH-1. Slow moving vehicles mainly consist of cycle, cycle rickshaw and animal drawn vehicles. In terms of PCU, traffic consists of 99.99% of fast moving vehicles for NH-1 and 1.31% of slow moving vehicles.
- f) The traffic consists of 95.44% fast moving vehicles and 4.56% slow moving vehicles on SH-6. In terms of PCUs, traffic consists of 96.13% fast moving vehicles and 3.87% slow moving vehicles.
- g) The traffic consists of about 13% vulnerable road users and 86% non-vulnerable road users on NH-1. A vulnerable road user is that user who is more prone to the road accidents. In terms of PCU, vulnerable road users (VRU) are about 4.5% and remaining are the non-vulnerable road users.

## 8. REFERENCES

- [1] Al-Ghamdi (1998), "Spot speed analysis on urban roads in Riyadh". Transportation Research Board, Washington, DC, 162-170.
- [2] CRRI (1990), "Road User Cost in India." A Report Submitted to Ministry of Surface Transport, Central Road Research Institute (CRRI), New Delhi.
- [3] Dey, P. P., Chandra, S, Gangopadhaya, S. (2006) "Speed distribution curves under mixed traffic conditions", J Transport Eng. ASCE: 132(6):475-81.

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- [4] Highway Capacity Manual, 2000.
  - [5] IRC: 64-1990, Guidelines for capacity of roads in rural areas (First Edition).
  - [6] James, H. Banks (1998), "Introduction to Transportation Engineering", WCB McGraw-Hill International Edition, Singapore
  - [7] Kadiyali, L. R., Lal, N. B., Satyanarayana, M. and Swaminathan, A. K. (1991), "Speed-Flow Characteristics on Indian highways" Journal of Indian Roads Congress, Vol. 52(2), pp. 233-251.