International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 12, December-2014, pp: (100-106), Impact Factor: 1.252, Available online at: www.erpublications.com

Signal Flow Characteristics for Heterogeneous Traffic Management System

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ABSTRACT: Knowledge of fundamental traffic flow characteristics and vehicle dynamic behavior are essential for operation of transportation system. The fundamental characteristics of speed and flow have been studied. Time-headway distribution of urban heterogeneous traffic was also studied. An appropriate methodology was adopted to collect and extract headway data. The methodology for choice of best fitting statistical distribution to the observed headway data has also been described. The result of the study has shown that, the headways of urban heterogeneous traffic can be modelled for vehicles over a wide range of traffic flow levels. Speed-flow curves for a selected road facility were plotted.

INTRODUCTION

The problem of measuring volume of such heterogeneous traffic has been addressed by converting the different types of vehicles into equivalent passenger r cars and expressing the volume in terms of Passenger Car Unit (PCU) per hour. The PCU is the universally dopted unit of measurement of traffic volume, derive dy taking the passenger car as the 'standard vehicle '.The interaction between moving vehicles in a traffic stream is highly complex and is influenced by a number of roadway and traffic factors. The accurate estimation of the magnitude of vehicular interaction for different roadway and traffic conditions is the prerequisite for better operation and management of roadway facilities in their prevailing conditions .Since the traffic flow phenomenon is influenced by several stochastic variables of random nature, micro simulation technique has been found to be a versatile tool to model complex traffic systems for study of their characteristics over a wide range of operating conditions. The present study is aimed at studying the vehicular interactions in heterogeneous traffic under different roadway and traffic conditions and hence check for the accuracy of the available PCU estimates for the different categories of vehicles on Indian roads for a range of traffic volume and roadway conditions.

The information on traffic volume is an important input required for planning, analysis, design and operation of roadway systems. Highway capacity values and speedflow relationships used for planning, design and operation of highways, in most of the developed countries, pertain to fairly homogeneous traffic conditions comprising vehicles of more or less uniform static and dynamic characteristics. But the traffic scenario in developing countries like India differs significantly from the conditions of developed countries in many respects. In Indian road traffic, the heterogeneity is of high degree with vehicles of widely varying static and dynamic characteristics. Under this condition, it becomes difficult to make the vehicles to follow traffic lanes. Consequently, the vehicles tend to choose any advantageous lateral position on the road based on space availability. Under the said traffic conditions expressing traffic volume as number of vehicles passing a given section of road per unit time will be inappropriate and some other suitable base needs to be adopted for the purpose.

The traffic condition in India is highly heterogeneous in nature and vehicles do not follow lane discipline which makes it difficult to study and analyze traffic flow characteristics. Traffic flow theories seek to describe in a mathematical way the interactions between vehicles and operators. To understand traffic flow, relationships have been established between the two main characteristics: flow and velocity. Velocity or Speed is the rate of movement of traffic and usually expressed in kilometer per hour. Speed is one of the important factors directly influencing mobility. Speed of the vehicles on the roadway is affected by drivers behaviour, Physical characteristics of the road, roadside interference, Weather, presence of other vehicles, etc. Speed is the important dynamic character to be studied. Flow or Volume is the number of vehicles passing a specified point during a stated period of time. It is expressed in vehicles per hour. The measurement of traffic volumes is one of the most basic functions of highway planning and management. Traffic volume counts are the most common measure of roadway usage, and they are needed as an input to the majority of traffic engineering analyses. The headway between vehicles in a traffic stream is of fundamental importance in traffic engineering applications. The time gap between successive vehicle arrivals, namely, time headway on a highway is an important microscopic traffic flow

characteristic that affects the safety, level of service, driver behavior and roadcapacity. Understanding time headways and their distributions will enable better management of traffic. It is expressed in seconds.

Figure 1: Heterogonous traffic

Purpose and Scope of the Guidelines

In order to facilitate the assessment of present and future traffic demands, for the development of need-based infrastructure accurate information and continuous monitoring of traffic by appropriate methods is necessary. Implementing authorities must therefore ensure that sufficient and appropriate data is available to undertake necessary planning, design, construction and maintenance of the country's road network, which is aimed at meeting the prevailing traffic flow, future traffic growth and loading without considerable deterioration in the quality of service. This guideline has therefore been prepared with the main aim being to provide basic information, concept and principles with respect to traffic data collection and analysis. There are various methods of data collection available and used by different organisations/institutions. This guideline, therefore, is only intended to provide guidance in respect of data collection and analysis, and allows for variation in the methodologies adopted by different users, planners, developers, funding authorities, etc. The beneficiaries of this guideline are Roads Department, other Ministries/Departments, local authorities, educational institutions, the private sector and individuals.

Role and Functions

Traffic Data Collection and projections thereof of traffic volumes are basic requirements for planning of road development and management schemes. Traffic Data forms an integral part in the science of descriptive national economics and such knowledge is essential in drawing up a rational transport policy for movement of passengers and goods by both government and the private sectors. This Guideline considers the fact that traffic flow data is important in planning of a particular section of the road network and for its subsequent maintenance. Traffic flow pattern appears to be random in distribution, as it reflects people's motivation in terms of different composition of vehicles on different types of roads under varying environmental conditions. It follows then that data being collected is a methodological statistics, because traffic flow pattern follows a random distribution. Despite such complexities, it does follow fairly and clearly defined patterns that are

possible to classify and analyse. Thus, traffic data collection and analysis follows varying trends and plays an important role in the evaluation and management of road network schemes. While taking cognisance of the above, traffic flow data is needed for different purposes by different Ministries and/or Organisations in Botswana.The major areas for which this data is required are:

- Planning prioritisation and project initiation.
- Project design.
- Planning maintenance.
- National Transport Statistics.
- Road Safety Measures.
- Traffic Control.

Some of the key areas in which traffic flow data is needed for development and management of the road network include:

a) Determination of a programme of road widening needs and general improvement or strengthening of existing road through a programme of reconstruction and construction of a new roads;

b) To check the efficiency of the road network by comparing current traffi c volume with the level of service or the calculated capacity;

c) To establish the relationship between traffic volume, number of accidents and causes thereof, as well as determination of the probable occurrences;

d) To plan prioritisation of roads improvement schemes;

LITERATURE REVIEW

Guidelines for Capacity of Urban Roads in Plain Areas - IRC106 (1990): This code recommends PCU values for various types of vehicles in urban roads and explains level of service criteria for urban roads. Vehicle Class wise Quantification and Headway Analysis under Heterogeneous Traffic (Kanagaraj et al., 2011). This paper aims to develop and analyze class wise time gap and following headway distribution models for different lead-lag pairs in mixed traffic using data from urban roads in Chennai. Headway distribution of heterogeneous traffic in urban arterials (Arasan and Khosy, 2003). This paper describes an attempt made to study the time-headway distribution of urban heterogeneous traffic over a wide range of flow levels. The importance of a systematic procedure for grouping of headway data through appropriate choice of class interval has been studied. Arasan and Arkathkar (2011) studied traffic flow characteristics on intercity highways using computer simulation. This paper covers data collection and speed-flow relationships for intercity highway.

Srinivas Peeta et al. (2003) modelled the car-truck interactions on freeway sections using microscopic traffic flow models. The car-truck interactions were modelled by associating a “discomfort level” for every non-truck driver in the vicinity of the trucks. It was observed that this discomfort is affect by the driver socioeconomic characteristics, and situational factors such as time-of-day, weather, and ambient traffic congestion levels. Al-Kaisy et al. (2005) found that the HCM suggested PCU factors for heavy vehicles is applicable only under free-flow conditions and hence, attempted to derive passenger car equivalents for heavy vehicles during congestion. It is found from the review of the literature that several studies on estimation of PCU values of vehicles in heterogeneous traffic have been conducted. For example, Terdsak and Chanong (2005) studied the effect of motor cycles on traffic operations on arterial streets of Bangkok. They found that the derived PCU of motor cycles showed a decreasing trend with increase in share of motor cycles in the traffic stream. Zhang et al. (2006) adopted the vehicle moving space (VMS) as the measure to derive passenger car equivalents for vehicles of different categories for Chinese roadway and traffic conditions. Chandra and Sikdar (2000) through an empirical study found that for a given road width, an increase in volume level of heterogeneous traffic causes more density on the road resulting in reduced uniform speed of vehicles. The lower speed difference between cars and subject vehicles yield smaller PCU value for the vehicle type. Chandra and Kumar (2003) studied the effect of road width on PCU of vehicles on two-lane highways and found that the PCU value increased with increase in width of roadway. Justo and Tuladhar (1984) developed mathematical models to derive PCU values for vehicles on urban roads based on empirical data under mixed traffic flow.

Ramanayya (1988) estimated the PCU factors for different vehicle types at different levels of services taking the Western car as the Design Vehicle Unit DVU. The review of literature on the subject matter reveals that studies conducted are mostly related to fairly homogeneous traffic conditions, and the few studies conducted under heterogeneous traffic conditions are not comprehensive enough to replicate the field conditions accurately. Hence, it was decided to make an attempt to study the vehicular interaction in heterogeneous traffic in a comprehensive manner and derive PCU values for different vehicle types through this research work.

DATA COLLECTION

The study site is located along the National Highway 10. It is a six-lane, divided urban road where a heterogeneous traffic condition prevails. One way (3 lane road) roadway width is 10 m. The parameters evaluated in this study are the classified count, speed and headway. The data was collected for one hour in the evening (5:00 to 6:00 PM).

Figure 2: Video camera location at overpass on the road

The volume count of vehicles carried out by recording the video and counting the number by playing the recorded video in the laboratory. Classified count for one minute interval was noted down and was used as the base data for comparison. Of all the vehicle categories observed, major five vehicle categories were considered to analyze. The following vehicular composition is observed.

THE SIMULATION FRAMEWORK

Simulation being a versatile tool for modelling traffic flow, the simulation technique has been used to study the heterogeneous traffic flow characteristics on Indian Roads by a few researchers in the past (e.g., Ramanayya (1988), Kumar and Rao (1996) and Marwah and Singh (2000)). These modelling attempts, however, are not comprehensive enough to replicate the field conditions fully due to various limitations of the studies. Research attempts made at IIT Madras (Arasan and Koshy, 2004 & 2005) to comprehensively model heterogeneous traffic flow has resulted in replication of the field conditions satisfactorily. This simulation model has been used to simulate the heterogeneous traffic flow over a wide range of roadway and traffic conditions. The model is capable of simulating the traffic flow for any specified composition and traffic volume on a given width of roadway over specified time duration. As the variables influencing the traffic flow are random and stochastic in nature, appropriate statistical distributions are used to represent them in the model. The inter-arrival times (time headways) of vehicles are randomly generated from specified statistical distributions. As per the

methodology, the entire road space is considered as single unit. The road space will be considered to be a surface made of small imaginary squares (cells of convenient size 100 mm in this case); thus, transforming the entire space into a matrix. The vehicles will be represented with dimensions as rectangular blocks occupying a specified number of cells whose co-ordinates will be defined before hand. The front left corner of the rectangular block is taken as the reference point, and the position of vehicles on the road space is identified based on the coordinates of the reference point with reference to the origin chosen at a convenient location on the space. This technique will facilitate identification of the type and location of vehicles on the road stretch at any instant of time during the simulation process (Fig. 3).

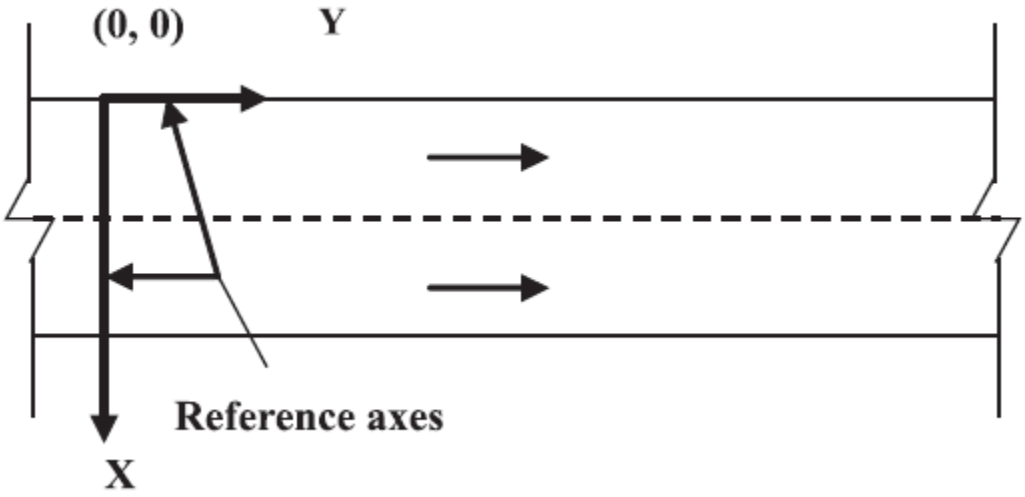

Fig. 3. Reference axes for representing vehicle positions

The simulation process, which is intended to model traffic flow through mid-block sections of urban roads, basically, consists of the following three modules: (i) Vehicle generation; (ii) Vehicle placement; and (iii) Vehicle movement. The flow chart shown in Fig. 2 depicts the major logical steps involved in the overall simulation process involving the three modules. For the purpose of simulation, the time scan procedure is adopted. The scan interval chosen for the simulation is 0.5 second. The arrival of vehicles on the road stretch will be checked for every 0.5 second and the arrived vehicles will be put on to the entry point of the study stretch of the road, on first-come-first-served basis. In the vehicle-generation module, the first vehicle is generated after initialization of the various parameters required to simulate heterogeneous traffic flow. Then, the generated vehicle is added to the system when the current time (clock time) becomes equal to the cumulative headway. At this stage, the module for adding vehicles named 'Add Vehicle' will be activated to facilitate the process. At higher traffic flow levels, there is a chance of more than one vehicle arriving during each scan interval (0.5s).

To address this issue, an additional clock for scanning with a precision of 0.05s is provided, so that a maximum of 20 vehicles can be added in one second. The precision of 0.05s, decided based on field studies, is intended to account for the maximum possible number of smaller vehicles, like motorised two wheelers, auto-rickshaw, etc. that may arrive in large numbers in short periods on multilane highways. Thus, the logic formulated for the model also permit admission of vehicles in parallel across the road width, since it is common for smaller vehicles such as Motorised two-wheelers to move in parallel in the traffic stream without lane discipline. Vehicles admitted to the simulation road stretch are then allowed to move based on the various movement logics formulated. Various manoeuvre for a vehicle moving on the simulation road stretch include free forward movement with desired speed, acceleration manoeuvre, movements leading to lateral shifting and overtaking of slower vehicles, movements involving deceleration and following of the front vehicle for want of sufficient gaps for overtaking, etc. When the cumulative precision time is equal to the scan interval, the module for vehicle movement 'Move All Vehicles' will be activated to move all the vehicles in the simulation road stretch, with their current parameter values. The above process will be continued until the clock time matches with the assigned total simulation time.

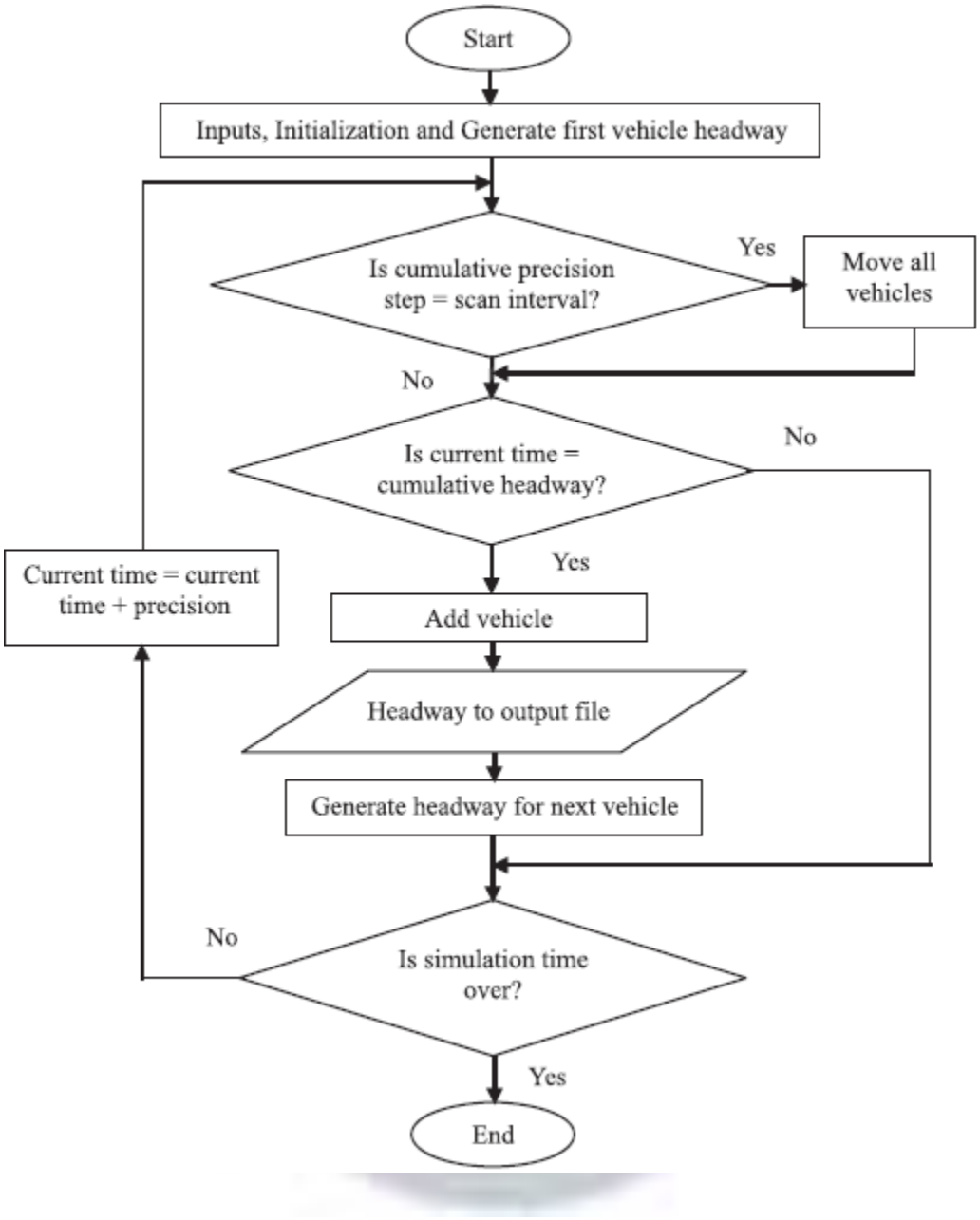

Fig. 4. Simulation framework

CONCLUSIONS

The following are the important conclusions drawn based on this study:

1. The validation results of the simulation model of heterogeneous traffic flow indicate that the model is capable of replicating the heterogeneous traffic flow on mid block sections of urban roads to a highly satisfactory extent. The validity of the model is further confirmed by the speed-flow relationships developed, using the simulation model, for 7.5 m, 11.0 m, andm 14.5 m wide road spaces, which are found to follow the well established trend of the speed-flow curves.

2. The PCU estimates, made through simulation, for the different types of vehicles of heterogeneous traffic, for a wide range of traffic volume levels indicate that the PCU value of a vehicle significantly changes with change in traffic volume.

3. It is found that, by virtue of the complex nature of interaction between vehicles under the heterogeneous traffic condition, at low volume levels, the PCU value of vehicles increases with increases in traffic volume, whereas under higher volume conditions the PCU value decrease with increase in traffic volume.

4. The results of the simulation experiment to study the effect of road width on PCU values indicate that for any vehicle type in heterogeneous traffic, the PCU value increases with increase in the width of road space.

5. The check performed to ascertain the accuracy of the PCU estimates by comparing the flow of carsonly and the PCU equivalent of heterogeneous traffic on 7.5 m, 11.0 m, and 14.5 m wide road spaces indicate that, the estimates are fairly accurate.

6. Thus, for the traffic condition considered for this study, there is reason to treat PCU value of a vehicle type as a dynamic quantity rather than treating it as a constant.

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