TRAFFIC FLOW MODELLING APPROACHES

CHAPTER 2

TRAFFIC FLOW MODELLING APPROACHES

2.0 INTRODUCTION

The efficient movement of people and goods through physical road and street system is an intriguing problem. Modelling of traffic flow gives insight into the traffic behaviour and enables better roads to be built. Study of traffic systems has been a lively subject of research and debate for traffic engineers over the last five decades. This has resulted in a variety of models describing different aspects of traffic flow operations. Many researchers in India have attempted to characterise the traffic flow in mixed mode environment. An overview of traffic flow modelling research in general and of simulation studies carried out on mixed traffic flow is presented in this chapter.

2.1 TRAFFIC FLOW CHARACTERISTICS

Researchers have been attempting to understand the behaviour of traffic systems through development of traffic flow models relating the three fundamental
parameters of traffic flow, viz., the speed, the volume and the density. The relationships between these variables vary depending on the characteristics of the traffic stream, which in turn are influenced by stream composition and the factors related to the vehicles, the roadway and the driver. The vehicular factors include the physical dimensions and the operating characteristics. The mixed traffic on our urban roads consists of vehicles belonging to different classes, whose physical and operating characteristics differ from one other considerably, resulting in very many flow conditions even at one location.

Researchers have broadly classified the traffic flow conditions as free flow, congested flow and transitional flow. In free flow condition, i.e. at very low densities, the vehicles will be unimpeded by other vehicles and will be moving freely. At high densities, vehicles will be influenced by the presence of other vehicles and will be constrained. While the interaction between vehicles is likely to be at minimum under free flow conditions, it will peak under congested flow conditions.

The concept of Level-Of-Service has been introduced in 1965 Highway Capacity Manual, dividing the operating conditions of traffic stream into six regions. While, Level-of-Service A corresponds to free flow condition, Levels-of-Service B & C represent the stable flow conditions. On the other hand, Levels-of-Service D & E are presented as unstable flow conditions. Level-of-Service F corresponds to forced flow conditions. The primary criterion for demarcating different Levels-of-Service has been the lane density, the other criteria used being, volume/capacity ratio and the operating speed. This indicates that interaction between vehicles vary depending on flow level.
Similarly, variations in operating characteristics can also be observed in mixed traffic. Indian Roads Congress (1990) has tentatively recommended six levels of service, more or less similar to that recommended in HCM (1965). However, the traffic, the roadway, the vehicular and the driver characteristics in India vary considerably from those prevailing in homogeneous and lane disciplined traffic conditions. In spite of the fact that many researchers have studied mixed traffic stream behaviour, the research carried out so far in India has not been successful to provide solutions to many practical problems. This can be due to the limitations of the approaches adopted by them. Hence, it becomes necessary to review the suitability of various methodologies available for modelling of mixed traffic flow and select a suitable methodology. A brief discussion of various methodologies used for study of traffic flow is given below.

2.2 CATEGORISATION OF TRAFFIC FLOW MODELS

Research on the subject of traffic flow modelling started some fifty years ago, when Lighthill and Whitham (1955) presented a model based on the analogy of vehicles in traffic flow and particles in a fluid. Since then, mathematical description of traffic flow has been a lively subject of research and debate for traffic engineers. Traffic flow modelling is increasingly attracting the interest of scientists. This is partly due to the great economical and social relevance of the traffic flow problem and partly to the interesting features, which are emerging from its study (Campari and Levi, 2002). This has resulted in a broad range of models describing different aspects of traffic flow operations.

The achievements of traffic modelling research during the last five decades can be classified according to the following:
➤ Scale of the independent variables (continuous, discrete, semi-discrete);

➤ Level of detail (sub microscopic, microscopic, mesoscopic, macroscopic);

➤ Representation of the processes (deterministic, stochastic);

➤ Operationalisation (analytical, simulation);

➤ Scale of application (networks, stretches, links, and intersections).

2.3 TRAFFIC STREAM PARAMETERS

The fundamental traffic stream variables of interest are the flow, the speed and the density. Flow \( q \) is defined as the number of vehicles passing a specific point in a given period of time and is expressed as an hourly flow rate (vph). The unique flow parameter is the maximum flow or capacity flow \( q_m \). Speed \( u \) is defined as the average rate of motion of traffic stream expressed in kilometres per hour (kmph). From theoretical considerations, space-mean speed should be employed and the two unique parameters of speed are the free-flow speed \( u_f \) and the speed at capacity flow (optimum speed, \( u_o \)). Density \( k \) is defined as the number of vehicles occupying a section of a roadway and is expressed as vehicles per kilometre (vpkm). The two unique density parameters are the jam density \( k_j \) and the density at capacity flow (optimum density, \( k_o \)). The inter-relationships among these three parameters are known as the traffic stream models and typical relationships are presented in Fig 2.1.
A set of two independent equations is required to fully define the traffic flow in terms of these three basic variables. One equation is provided by the dimensional analysis relating the three variables:

\[ q = k \cdot u \]  

Eqn. ......2.1

The other equation has to be obtained by empirical or other means. There are mainly three approaches for modelling of traffic flow, viz., the Deterministic, the Probabilistic and the Simulation approaches.

2.4 DETERMINISTIC APPROACH

In this approach, the relationships between the various quantifiable characteristics of the system under study are derived by empirical or analogy methods. The deterministic approach is the most appropriate for modelling the aggregate or macroscopic characteristics of traffic flow due to the simplicity and
ease of application of models. If the random variations of the system are very small, then the system can be treated as deterministic and this approach can be applied to derive the models related to the system. Also, if suitable data can be obtained, this approach can be easily applied.

2.4.1 Empirical Models

The models of Greenshields (1934) (Linear model), Greenberg (1959) (Logarithmic model), Underwood (1961) (Exponential model) and Drew (1968) (generalised model) are some of the empirical models which relate speed and density. Haight (1963) proposed the following five boundary conditions to be satisfied by a traffic stream model:

i) \( q = 0 \) for \( k = 0 \)

ii) \( q = 0 \) for \( k = k_i \)

iii) \( u = 0 \) for \( k = k_i \)

iv) \( u = u_f \) for \( k = 0 \)

v) \( \lim_{k \to 0} \frac{du}{dk} = 0 \)

Except the May and Keller's (1967) model, all the other relationships fail to satisfy one or more conditions. It means that a single model may hardly be able to describe the traffic flow over complete range of flow conditions.

Many researchers (Edie (1961), Underwood (1961), Ceder, (1976), Easa (1983)) reported the discontinuities, as shown in Fig 2.2, in freeway speed-flow-density data. They attributed this to the different mechanisms that affect the flow at different density levels and suggested the use of multi regime models to properly describe traffic behaviour. Hall et. al. (1986) concluded that cause of gaps in data could be backing of queue into the location where the flow is less than
capacity. Hall and Hall (1990) observed that the conventional parabolic relationship exists between speed and flow for a section upstream of a capacity restriction, whereas, at downstream the speed remains constant until a queue is formed upstream and then a vertical drop to lower speeds occurs at nearly same flow rate.

Chin and May (1994) observed that serious misinterpretations of speed-flow relationships could result if unsuitable data reduction and analytical procedures are employed and if the influence of study location on the nature of data is disregarded.

Modelling of mixed traffic by empirical approach had been the topic of study of many researchers [Mony et. al. (1978), Gupta et. al. (1979), Central Road Research Institute (1982), Thuladhar (1987), Sarna et. al (1988), Nagaraj et. al. (1990), Kadiyali et. al (1991), Kumar (1994) and Sahoo et. al.(1996)] in India. A
review of those works revealed that there have been no unified and generally acceptable relationships between the traffic stream parameters. This can be due to wide variations in traffic mix, vehicular and roadway characteristics that result in very many combinations of flow conditions. Development of a generalised flow model encompassing all the possible flow conditions may not be rational. Thus it becomes essential to divide the flow conditions into homogeneous regions and develop models for each of the regions separately.

As the flow conditions vary from location to location and over time, development of traffic flow models by empirical approach requires huge data, the collection of which may be uneconomical in our conditions. Further, it may be hardly possible to observe and record the data for all the ranges of flow conditions. Also, these models, being deterministic in nature, may not reflect adequately the individual driver-vehicle unit. Hence, the models developed based on empirical approach are likely to be of limited use for development of standards. Further, the availability of sufficiently long uniform sections, such that the influence of adjacent sections is minimum, in urban areas is quite rare.

2.4.2 Car-Following Models

Car-following models are microscopic models and are based on the dynamic behaviour of a following vehicle. Car-following models determine the acceleration or deceleration rate of the following vehicle in a given time interval based on the actions of the lead vehicles. Once the acceleration or deceleration rate of the following vehicle is determined, equations of motion are used to compute the speed and the position of the following vehicle for any given time interval. Many different car-following models have been proposed to describe
driver behaviour in a traffic stream. Brackstone and McDonald (2000) provides a historical review of car-following behaviour modelling. Driver behaviour literature suggests four different types of car-following models. These four types are:

- Stimulus – response car-following models;
- Safety-distance or behavioural car-following models;
- Psycho-physical car-following models; and
- Fuzzy logic-based car-following models.

Many researchers, Gazis et al. (1961) May and Keller (1967), etc., derived the macroscopic stream models from car-following models for steady state conditions. Even though, a microscopic treatment of traffic stream is possible by this approach, the car-following models are having certain limitations. In reality, the drivers get clues not only from their respective lead vehicles but also from other sources. So the response of the following driver will be much more complex than what is assumed in these models. Further, the theory applies only when the vehicles follow the lead vehicles and hence, can be applied to only high-density flow conditions. Hence, the car-following models fail to describe the traffic stream over the full range of flow conditions. In mixed traffic, vehicles hardly observe lane discipline and often move side by side in the same lane. So the application of car-following models for mixed traffic appears to be under a cloud. Brackstone et al (2002) concluded that much work remains to be done before car following can be even partially understood.

2.4.3 Fluid Flow Analogy Approach

Another approach of obtaining traffic stream models is fluid flow analogy approach. In this approach, the traffic flow is considered to be analogous to fluid

Many of these approaches to model traffic flow have not developed beyond the stage of formulation, may be due to the complexity of the formulation and the variety of the parameters required to describe the three processes. Despite the limitations, these approaches have provided valuable insight into various aspects of traffic behaviour and flow modelling (Gartner et al 1997).

Some of the dissimilarities between vehicular flow and the flow of molecules in a fluid or a gas are anisotropy, unaffected slow-vehicles, driver's personality, finite space requirements, consideration of the velocity variance and finite braking times and reaction times.

These models have the advantage that they enable description behaviours of individual vehicles, without the need to describe their individual time-space behaviour. However, the resulting equations have been criticised for having too many parameters and high dimensionality, hampering calibration and their real-time applicability. But, they are ideally suited as a foundation to derive macroscopic flow models. Moreover, using particle discretisation approaches, these models can be microscopically discretised.
Macroscopic models are suited for large scale, network-wide applications, where macroscopic characteristics of the flow are of prime interest. Generally, calibration of macroscopic models is relatively simple (compared to microscopic and mesoscopic models). However, macroscopic models are generally too coarse to correctly describe microscopic details and impacts, for instance caused by changes in roadway geometry. Due to the availability of closed analytical solutions, these are suitable for application in model-based estimation, prediction, and control of traffic flow.

2.5 PROBABILISTIC APPROACH

Stochastic models are built up from the causal mechanisms and their merit lies in providing an understanding of the flow process as related to fundamental characteristics of the drivers, the vehicles and the roadway. The variable nature of these characteristics gives rise to the stochastic nature of the various processes occurring in a traffic stream, viz., the speeds, the headways, the overtaking and the platooning.

The commonly used theory for traffic flow analysis is the queuing theory. In a traffic stream, the vehicles travel at different speeds, so the fast vehicles catch up the slow vehicles, resulting in formation of platoons. These platoons can be considered as moving queues. But there are certain differences between traffic operations and standard queuing system. The traffic still continues to flow even when the traffic intensity (ratio of arrival rate to service rate) is greater than unity. When one platoon catches another platoon, queues get amalgamated. Also, an overtaking may occur from any position in platoon and the specification of queue discipline becomes difficult. Further, the overtaking process is affected by driver
gap acceptance behaviour.

Some of the probabilistic models of traffic flow are the *Fast-vehicle Models* (Tanner, 1958), *Two-speed model* (Gordon and Newell (1964), Daganzo (1975)), *Integral Equation Model* (Erlander (1968), Jacobs (1974)), *Equilibrium Platoon Models* (Miller (1965), Gipps (1976) and Kallberg (1980)) and *No overtaking Models*. All these models included one or at the maximum two random variables in the formulation, whereas, traffic flow is a result of a number of random processes which interact in various ways. Attempts to include more random variables in the models have generally failed due to mathematical intractability. So a general model of traffic flow applicable to all situations is not yet available. However, the probabilistic approach provides an understanding of the causal mechanisms. So probabilistic models can be used for formulation of the models and the statistical methods can be applied to estimate the parameter values.

### 2.6 SIMULATION APPROACH

Simulation models are based on the (sub)microscopic approach in which the behaviour of individual components of the system is considered. The computer simulation of the system is made possible by integrating several models that describe the operating characteristics of the components. In simulation study, it is possible to include any number of factors, which may not be possible in mathematical models. A comprehensive simulation can be regarded as the equivalent of an idealised laboratory experiment. Simulation enables the experimenter to control the variables as in conjunction with observing real traffic. So it is possible to study the effect of independent variables on dependent variables. Another advantage of simulation modelling is the ability to simulate a
wide range of conditions with relative ease and without the expenses necessary
to obtain the field data. It is also possible to create combinations of road and
traffic conditions that are hardly observed but which are felt necessary to be
simulated by researchers. Because of these advantages, many researchers
have adopted computer simulation for modelling of traffic flow. Traffic flow
simulation models can be broadly classified as microscopic simulation models,
sub-microscopic simulation models and cellular automation models.

Gerlough (1956) was the first to use simulation technique for the study of traffic
flow. Cassel and Janoff (1968) developed a model known as Franklin Institute
Research Laboratories (FIRL) model to simulate traffic flow on a two-lane two-
way roadway. Some of the other researchers to work on simulation modelling of
traffic flow are Heimbach et. al.(1973), Gynnerstedt (1977), John and Kobett
detail many of these simulation models.

2.6.1 Microscopic simulation models

The availability of fast computers has resulted in an increasing interest in
complex micro-simulation models. These models distinguish and trace single
cars and their drivers. Driver's behaviour is generally described by a large set of
if-then rules (production-rule systems). From driver behaviour and vehicle
characteristics, position, speed and acceleration of each vehicle are calculated
for each time step. A large number of microscopic simulation models have been
developed.

2.6.2 Sub microscopic simulation models

In addition to describing the time-space behaviour of the individual entities in the
traffic system, sub microscopic simulation models describe the functioning of
specific parts and processes of vehicles and driving tasks. For instance, a sub
microscopic simulation model describes the way in which a driver applies the
brakes, considering among other things the driver's reaction time, the time
needed to apply the brake, etc. These sub microscopic simulation models are
highly suited to model the impacts of driver support system on the vehicle
dynamics and driving behaviour.

2.6.3 Cellular automaton models

A more recent addition to the development of microscopic traffic flow theory are
the so-called Cellular Automaton (CA) or particle hopping models. CA-models
describe the traffic system as a lattice of cells of equal size. A CA-model
describes in a discrete way the movements of vehicles from cell to cell (Nagel
al (2004)). The size of the cells are chosen such that a vehicle driving with a
velocity equal to one moves to the next downstream cell during one time step.

Using this minimal set of driving rules, and the ability to apply parallel computing,
the CA-model is very fast, and can consequently be used both to simulate traffic
operations on large-scale motorway networks, as well as for traffic assignment
and traffic forecasting purposes. CA-models aim to combine the advantages of
complex micro-simulation models, while, remaining computationally efficient.
However, the car-following rules of both the space-oriented and time-oriented
CA-models lack intuitive appeal and their exact mechanisms are not easily
interpretable from the driving-task perspective. Moreover, they are too crude to
describe and study microscopic details of traffic flow (e.g. overtaking and
merging) sufficiently accurate from a single driver's perspective. The dimensions
of vehicles in mixed traffic vary widely resulting in two vehicles moving side by
side in the same lane. The representation of vehicles as cells is a big question to be answered before this technique can be used for study of mixed traffic.

A large number of computer models have been developed for homogeneous traffic conditions in western countries. Algiers et al. (1997) identified 58 microscopic simulation models and analysed 32 models, given Table 2.1, as part of the ‘Simulation Modelling Applied to Road Transport European Scheme Tests (SMARTEST)’ project. They analysed the models based on Scale of application, Objects and phenomena modelled, Indicators, Interface, Control strategies and algorithms, Validation and limitations. They concluded that imperfect simulation of human behaviour is still an open-ended research problem.

**Table 2.1 List of Microscopic Simulation Models**

<table>
<thead>
<tr>
<th>CASIMIR</th>
<th>DRACULA</th>
<th>HUTSIM</th>
<th>MICSTRAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEMIS</td>
<td>NETSIM</td>
<td>PADSIM</td>
<td>SIGSIM</td>
</tr>
<tr>
<td>SIMNET</td>
<td>SITRA-B+</td>
<td>SITRAS</td>
<td>THOREAU</td>
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<td>AUTOBAHN</td>
<td>FREEVU</td>
<td>FRESIM</td>
<td>MIXIC</td>
</tr>
<tr>
<td>SISTM</td>
<td>AIMSUN2</td>
<td>CORSIM</td>
<td>FLEXSYT II</td>
</tr>
<tr>
<td>INTEGRATION</td>
<td>MELROSE</td>
<td>MICROSIM</td>
<td>MITSIM</td>
</tr>
<tr>
<td>PARAMICS</td>
<td>PLANSIM-T</td>
<td>TRANSIMS</td>
<td>VISSIM</td>
</tr>
<tr>
<td>ANATOLL</td>
<td>PHAROS</td>
<td>SHIVA</td>
<td>SIMDAC</td>
</tr>
</tbody>
</table>

2.7 **SIMULATION STUDIES IN MIXED TRAFFIC**

The first work in simulation study of mixed traffic in India is that of Marwah (1976). He developed a simulation model to study the behaviour of mixed traffic
on two-lane two-way roads. The minimum spacing between the vehicles was assumed to be deterministic. The overtaking logic used in his study permits overtaking of bunch of any number of vehicles, which may not be feasible in real life situation. The model could simulate only two or three categories of vehicles at a time.

Another important work is that of Ramanayya (1980), wherein he developed models to depict the operations on single lane one-way, two-lane one-way and two-lane two-way roads. He suggested only three Levels of Service for mixed traffic conditions. A new conversion unit called Equivalent Design Vehicle Unit (EDVU) to convert the different classes of vehicles including passenger cars to a standard or design vehicle (passenger car of developed countries) was suggested in his study. The details of the model are discussed in Table 2.2.

Palaniswami (1983) developed a simulation model by modifying Sweedish VTl model to accommodate slow moving vehicles and to assess the effect of congestion on road user costs. He used the model to study the mixed traffic behaviour on single lane, intermediate lane and two lane roads in rural areas. The models were calibrated by comparing the speed distributions. The event based scanning technique was used to scan and update the system. The simulation model was coded in SIMULA.

Bandyopadhyay and Marwah (1986) developed a simulation model for traffic flow on a city road. The simulated road system consisted of four lanes, with the two central lanes meant for trams, intersections and transit vehicle STOPs. Five types of vehicles including trams were considered for study. The vehicle manoeuvring logic included three broad categories of flow status of vehicles and
is based on lane concept. The scanning procedure adopted was a combination of time scanning and event scanning techniques.

Chalapathi (1987) developed a simulation model for multi lane unidirectional traffic on rural roads. His model is based on Sweedish VT1 model, which was earlier modified by Palaniswamy (1983). The model outputs included the road user costs for various alternate highway conditions.

Badarinath (1993) developed a model to simulate the mixed traffic flow on one-way roads of widths ranging from 3.5 m to 6.5 m at 1 m. increments. The position of vehicles across the width of the road was determined based on Convolution Theorem. The behaviour of driver in positioning vehicle in a dynamic traffic stream was represented by means of a new concept based on Information Theory. This process involved conversion of the information received by the drivers into bits and comparing these bits of information with the threshold values derived from the previous accident data. However, this concept needs to be validated. A detailed discussion of the model is presented in Table 2.2.

Kuncheria (1995) developed simulation models to study the mixed traffic flow on one-way roads, at bottlenecks, merging and diverging locations and on two-way roads in urban areas. The overtaking logic in this study was based on probability of accepting the available space in lateral direction. He reported that the simulation outputs such as the stream speeds and the flows remain practically unaltered, irrespective of the headway distribution model used for generation of vehicle arrivals, if the observations are taken after sufficiently long distance from the entry. He reported that the model could not replicate the high-density flow conditions. Some of the details of this model are presented in Table 2.2.
### Table 2.2 Summary of Three Simulation Models of Traffic Flow on Urban Mid-Blocks in Mixed Mode Environment

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Time scanning, 1 sec</td>
<td>Time Scanning, 1 sec.</td>
<td>Time Scanning, 1 sec.</td>
</tr>
<tr>
<td>Scanning Technique</td>
<td>8 Classes</td>
<td>6 classes.</td>
<td>5 classes.</td>
</tr>
<tr>
<td>Entry Process</td>
<td>Straight &amp; Horizontal</td>
<td>Straight &amp; Level</td>
<td>Straight &amp; Level</td>
</tr>
<tr>
<td>Road Geometry</td>
<td>One-way &amp; Two-way</td>
<td>One Way</td>
<td>One-way &amp; two-way</td>
</tr>
<tr>
<td>Type of Flow</td>
<td>Normal Distribution</td>
<td>Normal Distribution</td>
<td>Normal Distribution</td>
</tr>
<tr>
<td>Free Speeds(kmph)</td>
<td>Type</td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td></td>
<td>Cars</td>
<td>55</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>Bus</td>
<td>50</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>Truck</td>
<td>40</td>
<td>6.50</td>
</tr>
<tr>
<td></td>
<td>Auto-rickshaw</td>
<td>45</td>
<td>5.0</td>
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<tr>
<td></td>
<td>Two-wheeler</td>
<td>45</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>Cycle</td>
<td>10</td>
<td>1.5</td>
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<tr>
<td>Acceleration/ Deceleration Values</td>
<td>Uniform acceleration values as given by IRC Deceleration values from curves reported in Transportation Engg. Hand Book</td>
<td>Zero jerk acceleration models developed based on limited observations</td>
<td>Non-linear models Model parameters derived from limited observations</td>
</tr>
<tr>
<td>Flow Logic</td>
<td>Based on available &amp; required linear &amp; lateral clearances Generalised car following model</td>
<td>Based on available &amp; required linear &amp; lateral clearances and risk the vehicle is subjected to. Generalised car following model</td>
<td>Based on available &amp; required linear &amp; lateral clearances for different combination pairs of vehicles</td>
</tr>
<tr>
<td>Clearances Required</td>
<td>Considered in terms of percent accepted or rejected 'x' times the width of the vehicle. Based on limited observations</td>
<td></td>
<td>Exponential models derived from field observations</td>
</tr>
<tr>
<td>Internal Book Keeping</td>
<td>List Processing or Chaining</td>
<td>List processing or chaining</td>
<td>Circular Array concept</td>
</tr>
<tr>
<td>------------------------</td>
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<td>-----------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td><strong>Outputs</strong></td>
<td>Avg. speed of traffic stream &amp; each class of vehicles</td>
<td>Headways Average speeds Volume Group size (platoon headway: 2 sec.)</td>
<td>Headways Average speeds of stream and each class of vehicles Volume Density Composition</td>
</tr>
<tr>
<td>Distribution of headways</td>
<td>Classified volume count</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentration Avg. delay for each class of vehicles Number of Overtaking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Validation Criteria</strong></td>
<td>Speed distribution (6.6% to 8.6%) Average Travel Time Distribution of Headways Average Delay</td>
<td>Field validation Extent of platooning</td>
<td>Average Stream Speed (-2.6 to 5.9 %)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Results of Experimentation</th>
<th>Stream Composition (%FMV &amp; %SMV)</th>
<th>% of four wheelers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90-10</td>
<td>70-30</td>
</tr>
<tr>
<td>Volume (vph)</td>
<td>800</td>
<td>800</td>
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<tr>
<td>Speed</td>
<td>34.25</td>
<td>29.25</td>
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<tr>
<td>Maximum</td>
<td>42.50</td>
<td>37.25</td>
</tr>
<tr>
<td>Density</td>
<td>23.35</td>
<td>27.3</td>
</tr>
<tr>
<td>Capacity Values: Cars</td>
<td>2044</td>
<td>880</td>
</tr>
<tr>
<td>Buses</td>
<td>2270</td>
<td>1190</td>
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<tr>
<td>Trucks</td>
<td>2089</td>
<td>991</td>
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<tr>
<td>Auto-rickshaws</td>
<td>1865</td>
<td>910</td>
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<tr>
<td>Two-wheelers</td>
<td>3290</td>
<td>1370</td>
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<tr>
<td>PCU Values at Capacity</td>
<td>Car</td>
<td>0.98</td>
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<td></td>
<td>Bus</td>
<td>0.88</td>
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<td></td>
<td>Truck</td>
<td>0.96</td>
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<td></td>
<td>Auto-rickshaw</td>
<td>1.07</td>
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<td></td>
<td>Two-wheeler</td>
<td>0.61</td>
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<table>
<thead>
<tr>
<th>Level-of-Service</th>
<th>Group Size</th>
<th>Flow</th>
<th>Speed</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt;6</td>
<td>400</td>
<td>27</td>
<td>148</td>
</tr>
<tr>
<td>B</td>
<td>6-10</td>
<td>2000</td>
<td>26</td>
<td>70</td>
</tr>
<tr>
<td>C</td>
<td>10-13</td>
<td>4400</td>
<td>26</td>
<td>165</td>
</tr>
<tr>
<td>D</td>
<td>&gt;13</td>
<td>8000</td>
<td>27</td>
<td>290</td>
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</tbody>
</table>
Arasan and Koshy (2003) developed a discrete event simulation model with time scanning technique to simulate the traffic flow on urban roads of different widths for deriving capacity and service volume standards. They validated the model based on headway distribution and speeds. They found a decreasing trend in PCU values as their proportion in the traffic stream increased. They derived the capacity values for urban roads for three typical traffic compositions.

Even though a good number of simulation models have been developed by researchers, the research so far has not been able to describe the behaviour of mixed traffic on urban mid blocks. This may be due to the complexity of the mixed traffic, lack of instrumentation for collection of data required for development of component models, lack of understanding of the vehicular interaction process or lack of high-speed computer facilities with sufficient memory for simulation of such a dynamic and complex system.

The following conclusions are possible to be drawn from the above discussion:

i) The empirical approach may not be able to provide solutions to the mixed traffic flow for the reason that it:
   - Involves collection of huge data, which is impracticable due to the complexity of the system and lack of proper instrumentation.
   - Does reflect only aggregate behaviour
   - Is deterministic in nature and does not reflect the driver behaviour.

ii) The probability approach to traffic flow study results in mathematically intractable models due to the several inherent stochastic processes under mixed traffic.
iii) The mixed traffic is not amenable to study by any of the above two approaches.

iv) The simulation approach seems to be more appropriate for study of mixed traffic, for the following reasons:
   ➢ It is based on integration of easily understandable component models.
   ➢ Experiments can be conducted under controlled conditions.

Hence, it has been decided to study the characteristics of unidirectional traffic flow in mixed mode environment through simulation approach.

2.8 NEED FOR AN INTEGRATED APPROACH

Many of the relationships governing the individual vehicle manoeuvres in traffic flow simulation models are generally mathematical or empirical in nature. Also, in simulation approach, the simulated system is scanned or updated at regular intervals of time in accordance with stored instructions or rules of the model. The method of driver decision-making in simulation is rule based. However, in real life situation, a driver continually reviews his driving situation. As he scans the environment, his brain receives a stream of images or patterns defining the surrounding traffic situation. The data are fed to the brain in their raw state without any pre-processing. The driver's behaviour resulting from this input is probably based on a learned reaction to a particular situation described by the input, and therefore can be represented by a technique that follows this process more closely.

Artificial Neural Networks, which attempt to mimic the functionality of the human brain in a fundamental manner, provide the basis for a possible alternative modelling technique. In this approach, the collected data are presented directly
to the model without any processing and thus the approach has the potential to avoid the bias, which might be introduced due to subjective interpretation of the model builders. Neural network, considered as a black box for all practical purposes, by being exposed to a large data, identifies the relationships between a number of input parameters and the corresponding output parameters. Hence, it is proposed to use neural networks for describing some of the driving subtasks in this study.

2.9 CONCLUSIONS

An overview of the research on traffic flow modelling during the last five decades has been presented. The complex nature of traffic systems makes them an excellent application environment for simulation. Review of the mixed traffic flow simulation models revealed that the relationships used to represent the various subtasks are deterministic and do not reflect the driver behaviour. It is proposed to develop a simulation model of mixed traffic flow by integrating neural network models of some of the subtasks of driving.