SUMMARY, CONCLUSIONS AND SCOPE FOR FURTHER WORK

CHAPTER - 9

SUMMARY, CONCLUSIONS AND SCOPE FOR FURTHER WORK

9.1 SUMMARY AND CONCLUSIONS

9.1.1 Many traffic simulation studies that have been completed in mixed mode environment on Indian Roads have raised considerable doubts in the applicability of conventional speed-flow-density relationships. Some of the researchers have even pointed out that the speed-flow model appears more bell-shaped than being parabolic. Inspite of these doubts and conjectures, research work is continuing in India, as though, those observations are accidental and hence cannot be accepted as proven.

9.1.2 In this confused research background, the objective of the present work is to introduce certain orderliness in the experimentation and model building, so that consistency could be achieved in the results.

9.1.3 Exhaustive literature review in the present topic of interest has revealed that Simulation approach has been the most widely used for modelling of
traffic flow due to its many advantages over other approaches. Even those models that have been built using simulation approach have fallen short of expectations due to very many simplifying assumptions made in building up of component models.

9.1.4 Literature review has also revealed that neural networks, which mimic the human behaviour, have been successfully used for many traffic engineering applications. However, the neural networks need prior exposure in the form of training before application. Hence, it was felt that neural networks might not be able to provide total solution to the mixed traffic flow. Rather, they will be useful for representing some of the sub-systems.

9.1.5 Models of linear and lateral clearances, which form the most important component of the simulation model, were derived based on exhaustive data collected using video graphic technique.

9.1.6 The linear and lateral clearances were found to be dependent mainly on speed of subject vehicle for a given combination pair of vehicles. The relationship was observed to be linear.

9.1.7 The deviations of individual values of clearances from mean value for a pair of vehicles and for a speed range were found to follow normal distribution. The regression models of linear and lateral clearances were modified to reflect driver behaviour by adding a component, whose values follow normal distribution.
9.1.8 The placement of a vehicle with respect to surrounding vehicles in a traffic stream depends on a number of factors. The effect of many of these influencing factors is difficult to be directly observed and quantified in addition to being non-linear. Hence, Neural networks, which identify the input-output relations without any preconception or bias through training, were used for modelling linear spacings. The feed forward neural network with back propagation algorithm and with two layers (one hidden layer) was used for modelling these spacings. The optimum number of neurons in hidden layer was found to be ten. The performance of the neural network model was found to be superior to that of regression models both at calibration and validation stages.

9.1.9 The position of a vehicle across the width of the road, while being not under the influence of any other vehicle, need to be given separately and hence the models that describe the lateral placement of vehicles under free flow conditions form another component of simulation model. Analysis of the data collected at four locations of varying road width revealed that the lateral placement of vehicles depend on the type of vehicle, speed of vehicle and width of road. The variance of the distances maintained by any class of vehicles from the edge of the road was found to increase with increase in road width.

9.1.10 In simulation modelling, the generated vehicles are assigned the free flow speeds by sampling from speed distributions. Field surveys were conducted at four typical urban mid blocks to obtain the free speeds of different types of vehicles. The free flow speeds were found to follow normal distribution.
9.1.11 The threshold headway is generally used to distinguish free flowing and following vehicles. The threshold headway was determined by analysis of speed and headway data of vehicles, which were moving one behind the other, and it was found to be 3 sec.

9.1.12 Drivers steer their vehicles across the width to overtake another vehicle or to take the desired position across the width of the road and in such a way that no collision takes place. An attempt has been made in this study to determine the rate of lateral movement for different classes of vehicles. The rate of lateral movement was found to vary depending on the type of vehicle.

9.1.13 Car following models, which describe the behaviour of drivers reacting to the behaviour of their leaders, is another important component of traffic flow simulation model. In this study, the car-following behaviour of constrained drivers was modelled using both conventional response-stimuli method and neural network.

9.1.14 The parameters of conventional response-stimuli models were obtained by regression analysis. The optimum structure of the neural network was determined through trial and error process. The performance of neural and conventional stimulus-response models in predicting the speeds of each vehicle type was also compared. It was found that neural models performed better than car-following models during both training and validation stages.

9.1.15 Separate models were built to describe the acceleration characteristics of unconstrained vehicles. The data required for modelling of
acceleration/deceleration characteristics of vehicles was collected by a special method developed for this purpose. The average acceleration/deceleration values were found to be exponentially related with the speed of vehicle. These models were modified to reflect the driver behaviour by adding a term to the value obtained by regression model. Validation of the models was done by comparing the predicted acceleration/deceleration values with the actual values and the predicted values were found to be in close agreement with the actual values.

9.1.16 A computer model was developed by integrating the various component blocks for simulation of unidirectional traffic flow on a mid block section. The code for the simulation model was developed in 'C' language. Stack Data Structure was used for internal book keeping. The time scanning technique was used for scanning and updating the system.

9.1.17 Some of the salient features of the model are ability to simulate up to ten classes of vehicles, flexibility to change the length and width of simulated road, etc. The model has the capability of generating 100 sequences of random numbers so that each component process of simulated system can be described by a separate sequence of random numbers. An option was provided to randomise the seeds for generation of random numbers so that different sequences of random numbers can be used in different trials for a particular process.

9.1.18 The inter arrival times at the entry to simulated stretch were generated by sampling from exponential distribution. The model generates the free flow speeds of vehicles based on normal distribution.
The generated vehicles were moved through the simulated system as per the vehicle manoeuvring logic. A vehicle was classified based on one of five conditions based on the speed, positions of other vehicles in vicinity and available clearances. Separate functions were used to move a vehicle depending on its condition.

The output of the simulation model includes the stream characteristics such as the flow, the speed and the density at user selected points or stretches. The speeds of individual vehicles can also be obtained as output. The simulation model provides graphic display of the vehicles as they move through the simulated stretch. The model provides the user, the freedom to interject the program as per his/her requirement. The length of the warm up zone was determined by comparing the headways at various sections along the length of the simulated road. The length of warm up zone was obtained as 500 m based on frequency distribution analysis of headways. The warm up time was taken as 5 min.

Validation of the model was carried out in two stages. Firstly, it was checked whether the model is reproducing the general trends observed in real life situation. The model was found to be able to reproduce the general trend as expected in reality. The model was also validated by comparing the model outputs with the corresponding field data collected at two locations in Calicut city. The model was found to be reasonably good in replicating the field conditions.

In order to understand the behaviour of mixed traffic, a series of experiments were conducted on the simulation model by varying the
volume and the composition. Experiments were conducted for single vehicle streams and for various mix proportions. Regression analysis was carried out to derive the speed-density relationships for each of the experimental mixes. The speed-density relationship was found to be linear in all the cases. Using the derived speed-density models, stream parameters such as capacity flow and jam density were computed. Using the capacity flow values for single vehicle streams, the PCU values for two-wheeler, auto-rickshaw and bus were estimated.

9.1.23 Analysis of results of simulation experiments confirmed that the capacity flow increases with increase in percentage of auto-rickshaws in the stream for a given total percentage of cars and two-wheelers. Service volumes were determined for various levels of service using density as the criterion variable and the demarcation limits suggested by the HCM. Using the percentage reduction in speed as the criterion, the equivalent PCU values were obtained for different vehicles at various levels of service.

9.1.24 The major conclusions resulting from the experiments carried out on simulation model developed are:

i. There is no much justification in using models other than single regime linear model for modelling speed-density relationship in mixed traffic conditions. Consequently, the speed-flow and the flow-density models could be adequately described by parabolic relationships.
ii. The PCU values at capacity flow conditions for two-wheeler, auto-rickshaw and bus have been worked out to be 0.65, 0.85 and 1.49 respectively in this study.

iii. The capacity values for single vehicle streams of two-wheeler, auto-rickshaw and bus have been found to be 4335, 3334 and 1890 vph respectively in this study.

iv. A regression equation developed in this study based on 51 speed-density relationships for mixed vehicle combinations is able to predict the capacity of the mixed traffic very close to the reality. However, it is to be used only in situations of mixed traffic and not for streams with only single type of vehicle.

v. Experiments conducted by varying the percentage of auto-rickshaws in the traffic stream while keeping the two-wheeler and car percentages constant, have indicated that the capacity flow Vs percentage auto-rickshaw is linear, but those linear graphs for varying percentages of cars may intersect with one another, suggesting that there may be more than one mix combination for which the capacity flows may be identical. Hence, vehicles do interact to modify the capacity flow.

vi. Capacity flows in traffic stream is highly correlated with bus and two-wheeler percentage, but in opposite sense. This means that larger the percentage of buses the lesser the capacity flow. However, larger the percentage of two-wheelers greater the capacity flow. At or near capacity, the influence of auto-rickshaw percentage is very marginal. Similar inference, as in above, was possible for jam density also. But
the contribution of both the car and the auto-rickshaw percentages were found to be statistically significant in jam density calculations.

vii. Equivalent passenger car units calculated in this study for different types of vehicles at various levels of service have indicated that the PCU values for two-wheelers and auto-rickshaws vary quite considerably over different levels of service. On the other hand, change in equivalent PCU values for bus was found to be not very significant. Because of this reason, it was found that the auto-rickshaws and two-wheelers had significant contribution to make in the determination of capacity of traffic stream expressed in PCUs.

9.2 CONTRIBUTIONS OF THE STUDY

The major contributions of the study are

i. Development of a Neural Integrated Simulation model for experimentation related to vehicular movements in mixed traffic environment.

ii. Further refinement of basic simulation models by incorporation of linear and lateral placement of vehicles, acceleration/deceleration characteristics of vehicles, vehicle manoeuvring logic, etc, through neural network approach.

iii. Introduction of warm up zone approach in simulation modelling of traffic flow.
iv. Simulation of vast possible scenarios for a given set of input situation by randomising the seeds for generation of random number sequences.

v. Graphic display of simulated movements of vehicles and introduction of appropriate corrections to the flow logic when found necessary.

vi. Determination of capacity and jam density values for single and multiple vehicle streams by the development of a simple linear regression equation.

vii. Demonstration of the suitability of linear speed-density and parabolic speed-flow and flow-density models even in mixed traffic situation.

viii. Study of sensitivity of capacity values and jam densities to composition of the vehicles in the stream.

ix. Development of equivalent passenger car units and service volumes at different levels of service and study of variable PCU values.

9.3 LIMITATIONS OF THE STUDY

The developed simulation mode is useful only for one directional uninterrupted traffic movements under ideal geometric conditions. The effect of other influencing factors is not the subject matter of the present study. Separate
models have to be developed for bi-directional movement and for the study of influence of geometrical factors.

9.4 SCOPE FOR FURTHER WORK

The limitations of the study are the food for thought for further research in the field. Apart from this, it has been noticed from the results of simulation experiments, that the scatter of points in speed-density, speed-flow and flow-density plots are quite extensive, particularly near the capacity and free flow conditions. However, within the middle ranges, the scatter appears to be within reasonable limits.

These scatters particularly give rise to conjecture whether the idealised model of \( q = ku \) is valid in mixed traffic conditions. Fig 9.1 shows the scatter of points in the \( q/ku \) Vs density graph for car, two-wheeler, auto-rickshaw and bus only traffic streams, whereas, Fig 9.2 shows the scatter for three different mix combinations.

It is worthwhile investigating whether a modified equation of the form:

\[
q = cku
\]

where \( c \) is a dimensionless parameter, either independent or dependent on density could be built, so that the scatter of points in traffic stream interrelationships could be explained. 'c' appears to be a parameter related to the way in which the vehicles within the stream orient themselves, giving rise to series of gaps, similar to void ratio or porosity in soil structure.
Fig 9.1 q/ku Vs Density Plots for Single Vehicle Streams
Fig 9.2 q/ku Vs Density Plots for Selected Mixes