SYNOPSIS

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Degree for which submitted: **Ph. D.** Department: **Civil Engineering**

Thesis Title: **Development of a Comprehensive Microscopic Model for Simulation of Large Uninterrupted Traffic Streams Without Lane Discipline**

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Month and year of thesis submission: **October, 2007**

A good understanding of traffic stream behaviour is necessary for an efficient design of traffic facilities. One needs to understand how vehicles interact with each other and with the traffic facility in order to design such facilities better. That is, one needs to understand the stream behaviour under various traffic and roadway conditions. The stream behaviour, however, is complex because the traffic stream is an outcome of human driving process. Further compounding the problem of understanding stream behaviour is the fact that one cannot perform experiments with real-world traffic stream in order to understand how it behaves if certain parameters of the system are changed.

The complexity of stream behaviour and the difficulty that exists with performing experiments make computer simulation an important analysis tool in traffic engineering. Further, as computers have become more powerful the importance of simulation as an analytical tool has also increased since one can now hope to simulate large scale real-world situations in great detail. Another reason why simulation is important for studying traffic stream is that it is easier to build a stream by modeling individual vehicle actions in different situations than to understand the stream dynamics directly.

Driving "involves the maintenance of a safe speed and proper path relative to roadway and traffic elements."[1] A proper path involves proper positioning of the vehicle with

[1]Lunenfeld, H., Alexander, G. J., 1990. A User's Guide to Positive Guidance (3rd Edition) FHWA SA-90-017, Federal Highway Administration, Washington, DC.

respect to the road elements (like road edge, lane demarcation, surface deformities, etc.) and traffic elements (the vehicle ahead, vehicle to the side, etc.). The choice of speed is often an outcome of a driver's need to travel as quickly as possible and as safely as possible.

The primary tasks of driving therefore are (i) steering control through appropriate choice of steering angle, and (ii) speed control through acceleration/deceleration. Any model of driving or driver behaviour therefore must understand and model how drivers achieve the tasks of steering control and speed control under different roadway and traffic situations. It may be pointed out here that over a period of time, steering control and speed control are interdependent tasks and actions related to speed control often impact action relation to steering control and vice versa. Also note a driver's action is always impacted by both roadway features and other vehicles (present in its vicinity) and in reality it is very difficult to separate out the impact of one from the other. For example — the speed a driver drives at in a given situation is not only dependent on how close it is to the other vehicles but also dependent on features like road width, surface condition, etc. Thus a realistic model of driver behaviour must also be a comprehensive model, that is a system which models both steering and speed control under the impact of both roadway and traffic features. It may be noted that the driver's task for steering control becomes as important as speed control when lane discipline is weak or absent like in India.

Hence, in this thesis an attempt is made to develop a comprehensive microscopic simulation model which should capable of simulating the traffic stream with and without lane discipline. The scope of the comprehensive microscopic traffic simulation model developed here is limited to uninterrupted unidirectional traffic and is expected to simulate individual vehicle behaviour as well as traffic stream behaviour for (i) different vehicular densities, (ii) different road geometry, (iii) different surface conditions, (iv) different types of vehicles and vehicle mix, and (v) different traffic discipline (like drivers following lane discipline or not following lane discipline). This model, referred to as CUTSiM (**C**omprehensive **U**ninterrupted **T**raffic **Si**mulation **M**odel), consists of two modules; one of the modules define the actions of the vehicle aimed at controlling its lateral position on the road while the other module defines the actions of the vehicle aimed at controlling its speed. In this thesis the first module is referred to as the lateral control module while the second module is referred to as the longitudinal control module.

The lateral control module describes how a driver chooses a suitable steering angle to maintain his/her vehicle on the "best path." The best path is assumed to be one which allows a driver to move safely and at satisfactory speeds given the driving environment at that time. It is hypothesized here that in order to choose the best path the driver evaluates the goodness of each available path within its vicinity based on (i) the maximum distance headway available on the path, (ii) the difficulty in maneuvering towards that path, (iii) the obstacles present in and around the path, (iv) whether the path ends up (within a short time) leading the vehicle to the edge of the road, and (v) whether the path crosses the expected path of faster moving vehicles coming from behind (recall that the model does not assume lane behaviour as this is often absent in traffic conditions in India). Simple functions are defined to capture the impact of these factors on goodness of path. For example, a simple function relating the steering angle required to maneuver to the new path from the existing path is used to evaluate the goodness of a path based on the second criterion (difficulty in maneuvering) mentioned above. All these individual goodnesses are multiplied to determine the overall goodness of a path. It is assumed that the path which has maximum goodness among all the available paths is chosen by the driver as the best path.

The longitudinal control module defines the actions of the driver (in terms of acceleration or deceleration) which he/she employs to control the speed or alternatively the longitudinal position of the vehicle. It is postulated that the driver's behaviour can be classified in two types: (i) when the driver behaviour is not impeded by the actions of other vehicles, and (ii) when the driver behaviour is impacted by the actions of the leading vehicle on the chosen path. The first type of behaviour is referred to as "free-flow" behaviour while the other is referred to as "car-following" behaviour. In the free-flow behaviour, actions of the driver is assumed to depend on the difference between his/her desired speed (speed which one wants to maintain if not impeded by other vehicles for a given road condition) and the current speed. Actions of the driver in car-following behaviour is assumed to depend on the anticipated relative speed and the deviation of available distance headway from stable distance headway (distance headway at which a driver feels safe while moving at a given speed).

CUTSiM utilizes these two modules at every instant of time for each vehicle to simulate large traffic streams. CUTSiM employs a parallel update strategy. It has been seen that CUTSiM can simulate large streams very realistically with limited computation power. For example, it can simulate traffic streams with about 6000 vehicles moving over 40 km on a desktop computer (2.2 GHz processor and 32 GB RAM) in three-quarters of real time (i.e., to simulate 1 hour of such a traffic stream the simulation takes about 45 minutes). It must be noted that this time includes the time spent in continuous monitoring of various stream parameters at more than 100 points on the 40 km stretch.

CUTSiM is used to simulate single lane traffic streams as well as traffic streams on wide roads with and without lane discipline. In fact, it has been shown that lane behaviour can be obtained as a special case of "no lane behaviour" traffic streams. Further traffic streams on roads of varying widths and surface conditions with a variety of vehicle mix have been simulated. These simulated streams have been studied for their microscopic and macroscopic properties. Results from these studies and their comparisons with appropriate observations from real-world traffic streams have been used to validate CUTSiM. For example, Figure 1 shows the asymptotic stability property of a platoon of vehicles on a single lane traffic stream; Figure 2(a) shows a comparison of the speed distribution (obtained from a real-world traffic stream with mixed traffic and without

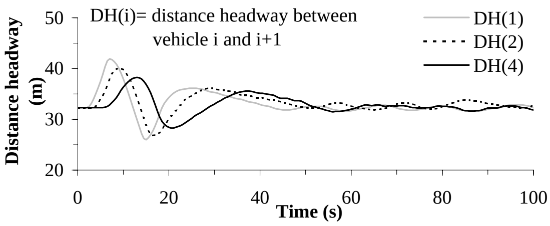

Figure 1: Study of asymptotic stability of a single lane traffic stream simulated using CUTSiM.

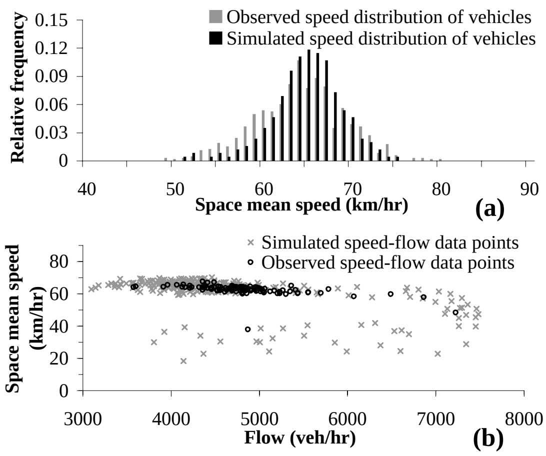

Figure 2: Comparison of (a) speed distribution and (b) speed-flow relation obtained from traffic stream at Delhi-Gurgaon highway, NH-8, (without lane discipline and with 70% passenger-car and 30% motorized two wheelers) with those obatined from a CUTSiM simulation of a similar stream.

lane discipline with those obtained from a CUTSiM simulation of a similar stream); and Figure 2(b) shows a comparison of the speed-flow relation (obtained from a real-world traffic stream with mixed traffic and without lane discipline with that obtained from a CUTSiM simulation of a similar stream).

The various studies carried out using CUTSiM include: (i) stability analysis in car-following situations (for single lane traffic), (ii) speed distribution studies, (iii) time headway distribution studies (except for the “no lane discipline” case), (iv) acceleration noise studies, (v) studies related to macroscopic speed-flow-density relations, (vi) impact of geometry and surface condition studies, and (vii) frequency of lane-change studies (for the case when lane discipline is maintained).

The above studies show that CUTSiM is able to simulate traffic streams with and without lane discipline on various kinds of roads with different vehicle mixes reasonably realistically. Although CUTSiM achieved some amount of success in modeling uninterrupted, unidirectional traffic stream with and without lane discipline there exists a lot of scope for further work on this model. For example, (i) attempt to be made to incorporate the impact of features such as shoulder width, horizontal and vertical alignments, etc. on driver behaviour; (ii) one has to study how well CUTSiM can handle traffic flow on weaving sections like on and off ramps; (iii) CUTSiM has to be extended so that it can handle bidirectional traffic; and (iv) model on gap acceptance behaviour of driver need to be incorporated so that CUTSiM can be extented to model interrupted traffic stream.