Abstract:
Intersections are an inevitable part of the road traffic system. If these are not designed properly, it can lead to several problems such as excessive delays, emissions and crashes. It is known that there are several points of conflict at the intersections that could cause crashes. Almost 49% of the total traffic crashes have been seen near intersections (MoRTH, 2016). Furthermore, studies also show that vehicle emissions are relatively higher during the acceleration or deceleration phase, which occurs at the intersections. It is difficult to understand traffic behaviour at the intersection as different activities, such as phase changes, multi-directional movements of vehicles, etc., occur at the same time. Proper intersection design can help to reduce delays, queues, emissions and crashes.

Various models are used to understand traffic behaviour, such as microscopic, mesoscopic, and macroscopic models. Microscopic models consider traffic as individual drivers-vehicles objects, whereas macroscopic traffic models analyze aggregated traffic. Mesoscopic models are hybrid macroscopic and microscopic models. This study attempts to simulate the signalized intersections in a multi-lane heterogeneous traffic environment with a microscopic simulation approach. The simulation was done in order to understand the driver behaviour at the signalized junction and to estimate the delays and emissions occurring at intersections. The simulation model developed in this research was built with the help of modified Cellular Automata (CA) rules in the MATLAB® environment.

This research consists of five parts: The first is the boundary selection of the simulation model. Second, the modelling of signalised intersections with multi-lane heterogeneous traffic. In the third part, the rules for cellular automaton near and away from the intersection were formulated. Fourth is the modelling of driver behaviour. Finally, the emission estimation was also included in the model.

Cellular automation models may have two types of boundaries: open boundaries where the vehicles are deleted at the end of the approach; closed boundaries where the number of vehicles is fixed for the complete simulation time. There are several problems associated with the modelling of intersections using closed boundary CA models. Some of the problems such as: low simulation speeds and excessive warm-up times can be overcome with open boundary CA models. Hence, the open boundary models were further investigated in this study.

Once the boundary conditions were determined, the simulation model with multi-lane and heterogeneous traffic was modelled with the help of CA. The model was designed to allow vehicles to use neighbourhood gaps to move. As a result, some important interactions taking place near the intersections such as seepage behaviour, was incorporated into the model. In the seepage behaviour the smaller vehicle sees through the gaps between large vehicles and reaches the stop line near the intersection. Seepage behaviour is one of the important

phenomena frequently observed at the signal intersection when the signal turns red.

The model developed in this study considers the zone of influence to segregate the behaviour of drivers at mid-block to those near the stop line. Zone of influence was calculated with the GPS data collected on 300 vehicles of three types: Car, Two-wheeler, Motorized-three-wheeler. A total of 100 data samples for each of the vehicle types were collected for generating trajectories. These trajectories were used to identify the vehicle driving behaviour such as speed and acceleration. Different rules for the vehicles before and after the intersection were proposed.

It was found that the zone of influence of intersection is different for various vehicles. The average of distances when vehicles start reducing their speed before the intersection after seeing the red signal at the intersection is 90.67 m. Many studies classified drivers into broad categories based on accelerations such as aggressive, timid or normal drivers. In this study it was found there were no such distinct groups based on field observations. Instead, there could be more categories that follow a distribution rather than the emission estimation was also included in the model.

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Further, the GPS data was also used to classify the drivers, but no particular number of groups of drivers were found, hence a different data set through video was collected at the intersections in Delhi and Mumbai, India. An attempt was made to model the driver behaviour as a distribution. A video data extractor tool was developed to extract traffic data such as trajectories, flow and speeds of vehicles.

The final model was calibrated and validated with the data collected in Delhi and Mumbai (India). Seepage behaviour and trajectories were compared with a simulator VISSIM and it was found that it does not satisfactorily simulate these behaviours. Delays obtained from several highway capacity manuals were compared with field and simulated data. Delays obtained from Indonesian and Canadian manuals were comparatively closer to the delays obtained in the field, whereas delays obtained from Indo-HCM and HCM were overestimating. Moreover, the delays obtained from the proposed model were found to be closer to the field delays. Further, this study can also be applied to simulate driver behaviour, signal timing optimization etc.

Overall, this study focuses on the simulation of heterogeneous, non-lane-based traffic conditions. It includes seepage and driver behaviour. It has been calibrated and validated with Delhi and Mumbai data. This model can be useful for the comprehensive analysis of a signalised intersection.