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Impacts of traffic-flows on vehicular-exhaust emissions at traffic junctions

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ABSTRACT

This paper examines the impact of traffic-flow on CO, NO_2 and PM emissions at two distinct traffic junctions and evaluates the use of emission factors. The study includes three scenarios regarding pollutant emissions, which combine a field, experimental and semi-empirically estimated traffic parameters for free, interrupted and congested traffic-flow conditions. It evaluates the emission patterns for heterogeneity in traffic characteristics of both junctions. The results suggest the corrections to be made to emission factors at traffic junctions for better forecast of air quality.

1. Introduction

The problem of emissions is generally most critical at traffic junctions like intersections and roundabouts of urban centers. Vehicles undergo different modal events and speeds with frequent interruptions while maneuvering the junctions and thus relationship of emissions to traffic-flow characteristics varies by traffic mix when vehicles do not follow a strict-lane discipline. Traffic-flow is often interrupted with frequent start-stops, delays and speed-change cycles at intersections leading to a severe congestion and longer queues, which, however, occur rarely at roundabouts.

Here, quantify the emissions of CO, NO_2 and PM for the traffic characteristics observed at a signalized intersection and a conventional two-lane roundabout in response to traffic-flow pattern. To do this an analysis of the semi-empirical relationship of traffic flow with the traffic density and pollutant emissions for a free, interrupted and congested flow condition is conducted. The free-flow points to no-stop condition that may occur during a lean traffic, the interrupted-flow points to stop-and-go condition that may occur during a vehicle-to-vehicle or vehicle-to-pedestrian interactions, and the congested-flow points to a longer queue formation with a highly reduced speed, stoppage of vehicles at an intersection and slowdown of a vehicular movement at a roundabout. Further, the calculation on pollutant emissions for three scenarios, each with alternate combinations of field, experimental and semi-empirically calculated traffic parameters; the inter-comparison, critical evaluation, and identification of the pollutant-wise corrections to be applied to emission factors for calculating emissions at traffic junctions.

2. Fieldwork and analysis

Two traffic junctions in two different cities of India, a heavily trafficked signalized intersection (Fig. 1a) in New Delhi and a non-signalized roundabout (Fig. 1b) in Guwahati are selected. The modal shares shown in the figure vary and exhibit dynamic and different traffic characteristics in particular of speed and density at both junctions. A manual traffic count was done a full week in 2008 and an average fleet speed for free, interrupted, and congested flows, delay-time at signals, and the time- and space-mean speeds were found. The vehicle counts were classified into four categories depending on the

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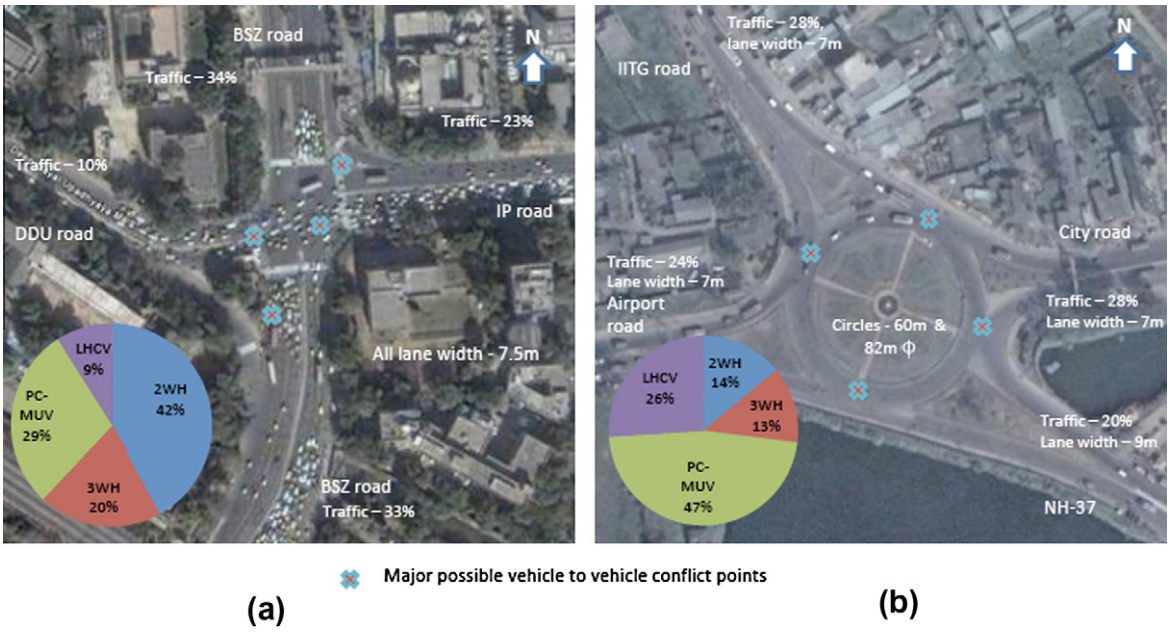

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Fig. 1. (a) A signalized intersection with the modal shares in New Delhi; (b) a non-signalized roundabout with the modal shares in Guwahati.

vehicle type, vintage and fuel use. These data were then used to calculate lane-width based passenger car unit (PCU) and traffic density using standard traffic flow and modified density methods.

Emissions are calculated for three scenarios. The first uses a semi-empirical relationship of traffic density with the flow rate and the observed average speeds in the three flow conditions. The second, density with a space-mean speed at the observed flow condition at different times of a day. These scenarios use COPERT-IV (COPERT IV, 2007) speed-dependent emission equations, while, the third uses the emission factors of Indian vehicles developed by the Automotive Research Association of India (2007) (ARAI) and density calculated using space-mean speed. This analysis quantifies the emission pattern at both junctions in various modal events, for heterogeneous modal-shares and different flow conditions.

2.1. Traffic analysis

Traffic densities, space-mean speeds, fleet speeds at each flow condition, and lane-width based PCUs were estimated. The hourly traffic-flow rates were classified in four categories including two-wheelers – motorcycle, moped and scooter (2WH), three-wheelers – auto rickshaw (3WH), passenger-cars and medium-utility vehicles – car, van, and jeep (PC-MUV) and light and heavy commercial vehicles – minibus, urban bus, truck (LHCV). Traffic counts were aggregated for every hour from 09:00 to 21:00.

Two approaches were used. In the first (A-I), the traffic flow was recorded at sites during free-flow representing no-stop, interrupted-flow representing stop-and-go and congested-flow representing close to jam conditions and traffic densities were calculated for each of the flows. The time-mean speeds obtained from the field observations for each vehicle category were approximately, during free-flow conditions, averaged to about 53 km/h; during interrupted-flow conditions, to 38 km/h; and during congested-flow conditions, to 19 km/h. Equation that defines traffic density is used to develop coefficients.

$$D_j = \sum_{i=1}^{N} \frac{T_i}{u_{i,j}} \tag{1}$$

where D_j is the traffic density in jth flow condition, T_i the traffic flow rate for ith vehicle category, $u_{i,j}$ the corresponding speed for ith vehicle category and jth flow condition and N is the number of vehicle category.

In the second approach (A-II), the space-mean speeds of each vehicle category is used for calculating the lane-width based densities and PCUs. It is calculated from vehicle counts in each category, lane-width of each arm in the case of roundabout and each link in the case of intersection, and the speed. The weight-averaged space-mean speed for every hour with a lane-width, traffic-flow rate and percentage composition of each vehicle type is used in calculating densities, speeds and PCUs by the following equations (Tiwari et al., 2007).

$$D_i = \sum_{i=1}^{N} \frac{(T_i/W)}{u_{s,i}} \tag{2}$$