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Development of emission factors for motorcycles and shared auto-rickshaws using real-world driving cycle for a typical Indian city

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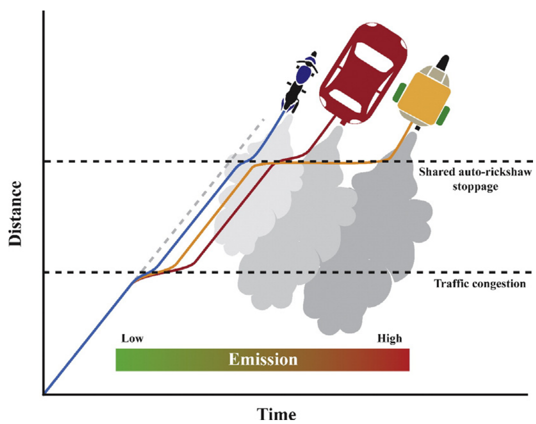
HIGHLIGHTS

- Real-world DCs were developed for typical Indian shared auto-rickshaws.
- EFs using real-world DCs differed significantly than EFs from legislative DCs.
- Real-world DCs for shared auto-rickshaws yielded high EFs.
- Number of passengers in shared auto-rickshaws linearly affected EF of CO.

GRAPHICAL ABSTRACT



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ABSTRACT

Vehicular emission is one of the most important contributors of urban air pollution. To quantify the impact of traffic on urban air quality, it is necessary to quantify vehicular emission. In many cities of India, such as Dhanbad, shared auto-rickshaw is the pre-dominant mode of transportation. Indian Driving Cycle (IDC) and Modified Indian Driving Cycle (MIDC) are used for emission testing of motorcycles, shared auto-rickshaws and passenger cars in India for regulatory purposes. IDC used for motorcycles and shared auto-rickshaws does not recognize the difference in two vehicle classes in terms of driving pattern. In real world, shared auto-rickshaws, behave differently than motorcycles. To quantify the impact of shared auto-rickshaws on urban air quality accurately, emission factors (EFs) are required to derive from real-world driving cycles (DCs). In heterogeneous traffic, vehicles of one class affect the behavior of vehicles of other classes. To estimate the emissions from different vehicle classes accurately, EFs for motorcycles and passenger cars are also required to be revised. In this study, real-world DCs were developed for motorcycles, shared auto-rickshaws and passenger cars in Dhanbad. Developed DCs were used to calculate EFs for respective classes. Shared auto-rickshaws were found to have the highest deviation from EFs derived using IDC.

1. Introduction

Air pollution due to vehicular emission is a major environmental issue as well as an important health concern for the inhabitants of

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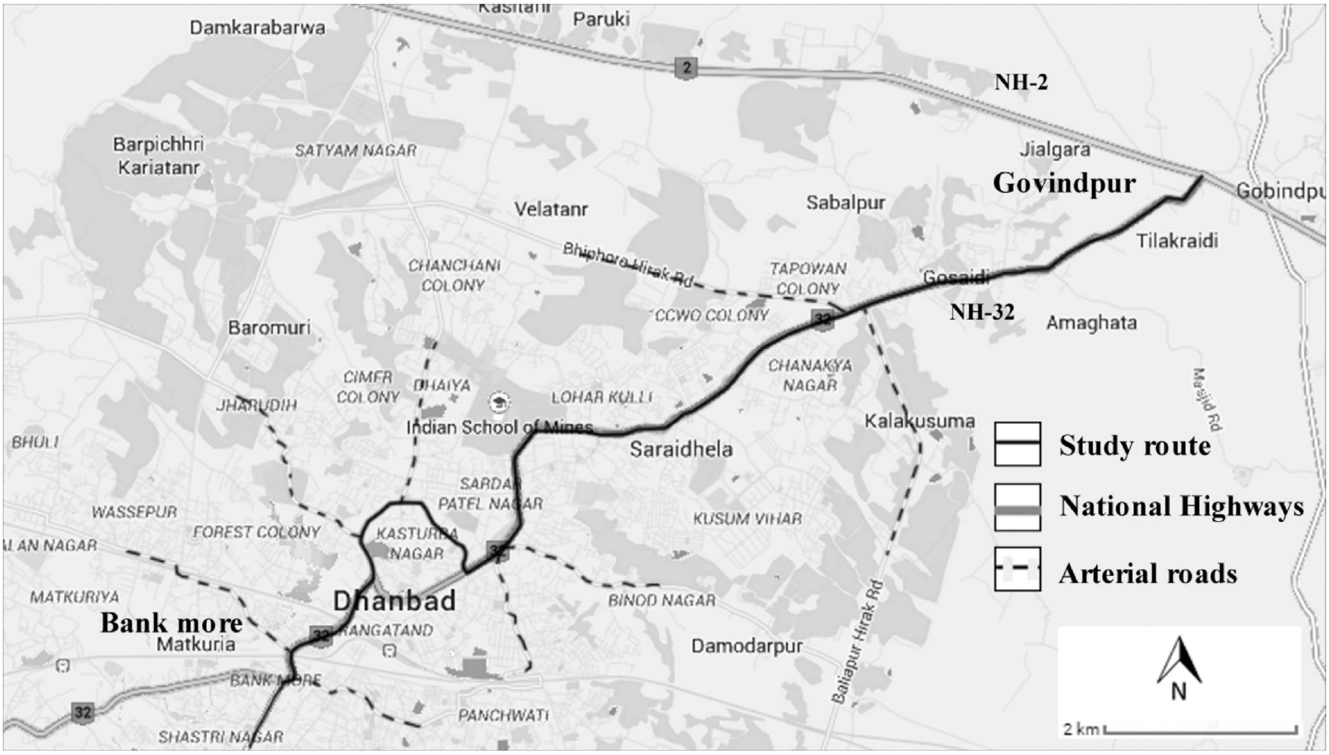

Fig. 1. Study route for speed profile measurement to generate representative DCs for motorcycles, shared auto-rickshaws and passenger cars in Dhanbad (Base map source: "Dhanbad" Map. Google Maps. Google, 10 Dec. 2014. Web. 10 Dec. 2014.).

large cities and sub-urban areas (Lakshmanan et al., 2015; Kamal et al., 2015; Zhang and Batterman, 2013). World population of vehicles increased drastically in last two decades. In 1994, worldwide population of passenger cars was 98.305 million. In 2012 the population increased to about 773.323 million (Davis et al., 2014). Rapid growth in number of vehicles and lack of required road facilities lead to severe traffic congestion in intra-urban roadways especially at intersections and hence affect the driving pattern. Moreover, heavy movement of vehicles during peak-hours aggravates the congestion phenomena. Stopping delay and approach delay due to traffic congestion lengthen the total travel time and consequently increase the total emission from the vehicles. Moreover, vehicles in accelerating and decelerating mode of driving are found to emit pollutants in different quantity (Coelho et al., 2005; Hung et al., 2005; Ahn et al., 2002; Frey et al., 2001; Rouphail et al., 2001). So, the fraction of time a vehicle spends in different modes also has significance in pollutant emission.

To design any policy to minimize the traffic associated emission and its exposure to human beings, the detailed understanding and accurate site-specific quantification of vehicular emission is very crucial. Emission models play a very important role to serve this purpose. Emission models can estimate vehicular emission using both average travel speed and second by second speed–time profile. Macroscopic or average speed emission models (eg. MOBILE) do not account for speed change in small scale due to traffic congestion and are unable to recognize different driving modes, which results in uncertainties in emission estimates. On the other hand modal emission models focus on intricate details of traffic dynamics and consider variations in emission rates due to different driving modes. Some of the existing modal emission models such as, Comprehensive Modal Emission Model (CMEM) (Barth et al., 2000), VT-Micro (Ahn et al., 1999) require second-wise vehicle speed data to calculate instantaneous emission rates. Furthermore, they are used to derive acceleration and % time spent in each driving mode.

Driving cycles (DCs) of a particular region provide a generalized estimate of speed–time profile and modal distribution in terms of duration and frequency. There are two types of DCs in use: legislative DCs and real world DCs. Legislative DCs are used to test emission from all mass produced vehicles to get authorization for selling in market. In India, Indian Driving Cycle (IDC) and Modified Indian driving cycle (MIDC) is used for legislative purpose. MIDC is 108 s long speed profile consisting of 16 s of idling, 13 s of cruising, 42 s of accelerating and 37 s of decelerating period (MoRTH, 2010). In real world, speed–time profile differ city to city as each city has its unique features such as topography, average width of roads, composition of vehicle fleet etc. Vehicle type, traffic facility type and time of the day also influence the speed–time profiles (Yu et al., 2010; Kamble et al., 2009; Saleh et al., 2009; Hung et al., 2007; Ericsson, 2001). For example, many cities in India lack

Table 1
Specification of different vehicle categories used in present study.

Parameters		Motorcycle	Shared auto-rickshaw	Passenger car
Mass of vehicle + passengers (kg)		127 + 130	695 + 480	1650 + 240
Frontal surface area (m^2)		1.39	2.5546	2.5546
Wheel diameter (m)		0.62	0.25	0.38
Gear Ratios	1st	3.00	3.32	3.81
	2nd	1.69	2.09	2.25
	3rd	1.20	1.35	1.51
	4th	0.875	1	1
Drag co-efficient		0.7	0.7	0.48

Table 2
Indian emission standards for motorcycles and three-wheelers used in present study (ARAI, 2011).

Type of vehicle	Sub-category	Vintage	Fuel	Emission factors		
				CO	HC	NO_x
Motorcycle (4 s)	100–200 cm^3	Post 2000	BS-II	1.48	0.50	0.54
Three wheeler diesel	<500 cm^3	Post 2005	BS-II	0.41	0.14	0.51
Passenger cars (Diesel)	<1600 cm^3	Post 2005	BS-II	0.06	0.08	0.28