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Development of driving cycles for passenger cars and motorcycles in Chennai, India

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ABSTRACT

Road transport is a significant contributor of pollutant emissions in the cities of developing countries. Driving cycles are required for the estimation of fuel consumption and exhaust emissions from vehicles for emission testing and certification, with many cities having unique cycles for different types of vehicles and roads. However, no driving cycle has been developed for passenger cars and motorcycles in Chennai, India. Thus, the aim of the present study was to develop representative driving cycles for passenger cars and motorcycles which reflect the real-world driving conditions in Chennai, India. On-board diagnostic (OBD) reader and Global Positioning System (GPS) receivers were used to collect second-by-second vehicle speed from a representative set of vehicles for developing the driving cycles. Eleven assessment measures were used in the construction of the driving cycles from the micro-trips. The developed cycles for motorcycles and passenger cars were of 1448 and 1065 s (peak-hour), which were further compared with existing driving cycles. Significant differences were observed between the cycles, thus highlighting the need for city-specific cycles.

1. Introduction

Passenger cars and motorcycles constitute a major share of the total vehicles in developing countries. In India, they are among the fastest growing vehicle types, mainly due to inadequate public transport facilities. In Tamil Nadu, the number of motorcycles increased from 0.37 million in 1993 to 10 million in 2016, whereas, the number of passenger cars grew from 0.25 million to 1.98 million during the same period (State Transport Authority, 2016). This growth in vehicles over the last two decades also saw air quality in many cities deteriorate drastically. Further, research on air quality and vehicular emissions is urgently required to inform policy makers and make cities liveable.

Driving cycles characterize the behavior of vehicle on the road by a series of acceleration, deceleration, idling, and cruising events, and, have a wide range of uses, from designing traffic control systems to determining the performance of vehicles. More importantly, it is used in the emission testing of vehicles for certification of emission norms.

Driving cycles have been developed for different cities to represent their local traffic and driving conditions as shown in Table 1. Each cycle is unique due to different traffic conditions, data collection technique, and vehicle type considered in the study. This uniqueness is also reflected in the variation in cycle duration; for example, Sydney cycle has a duration of 637 seconds (s) whereas Singapore cycle has a duration of 2344 s.

A driving cycle is made up of micro-trips (trip between two idling periods) and has a duration of about 10–40 min (Amirjamshidi & Roorda, 2015). This duration has to be long enough to contain enough micro-trips to reflect real-world driving behaviour but short enough to facilitate testing of many vehicles in the laboratory (Hung et al., 2007; Lai et al., 2013).

There are generally three steps in the development of a driving cycle: route selection, data collection, and cycle construction. Route selection involves selecting a representative route which captures the variations in road conditions within the study area. The route may consist of expressways, arterial roads, and sub-arterial roads. In data collection, the second-by-second speed of a vehicle driven on the chosen route is recorded either by chase-car method or on-board measurement (Hung et al., 2007; Kamble et al., 2009; Tzirakis, Pitsas, Zannikos, & Stournas, 2006). The cycle construction step consists of separating the entire data into micro-trips, determining the assessment parameters of the micro-trips and the entire data, and developing a driving cycle by combining those micro-trips which satisfy the assessment criteria.

There have been a few studies in India on driving cycles. Badusha and Ghosh (1999) and Nesamani and Subramanian (2011) developed driving cycles for buses in Delhi and Chennai, respectively, whereas Kamble et al. (2009) developed driving cycles for passenger cars in Pune. However, no driving cycle has been developed for passenger cars

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Table 1
Existing local and international driving cycles and their characteristics.

Region	Duration/distance	Vehicle type	Data collection technique	Reference
Sydney	637 s	PC	Chase-car technique	Kent, Allen, and Rule (1978)
Melbourne	980 s	PC	Chase-car technique	Watson, Milkins, and Braunsteins (1982)
Taipei	950 s	MC	Chase-car technique	Tzeng and Chen (1998)
Hong Kong	1471 s	PC	On-board measurement	Tong, Hung, and Cheung (1999)
Europe (Urban)	1000 s	PC	Car-chase technique	Andre (2004)
Taipei	760 s	MC	Chase-car technique	Tsai, Chiang, Hsu, Peng, and Hung (2005)
Hong Kong	1548 s	PC	Chase-car + on-board measurement	Hung, Tong, Lee, Ha, and Pao (2007)
Beijing	1090 s	PC	Chase-car technique	Wang, Huo, He, Yao, and Zhang (2008)
Pune	1533 s	PC	Chase-car technique	Kamble, Mathew, and Sharma (2009)
Hanoi	2061 s	MC	On-board measurement	Tong, Tung, Hung, and Nguyen (2011)
Chennai	9.6 km	Transit bus	On-board measurement	Nesamani and Subramanian (2011)
Edinburgh (Urban)	770 s	MC	Chase-car + on-board measurement	Saleh, Kumar, Kirby, and Kumar (2012)
Beijing	1084 s	Transit bus	On-board measurement	Lai, Yu, Song, Guo, and Chen (2013)
Singapore	2344 s	PC	Chase-car + on-board measurement	Ho, Wong, and Chang (2014)
Celje	2453 s	PC	Chase-car	Knez, Muneer, Jereb, and Cullinane (2014)
Khon kaen	1164 s	MC	On-board measurement	Seedam, Satiennam, Radpukdee, and Satiennam (2015)
Toronto	1800 s	Trucks	Simulated data	Amirjamshidi and Roorda (2015)

PC: Passenger car; MC: Motorcycle

and motorcycles in Chennai, India. Thus, there is a need for developing a driving cycle for passenger cars and motorcycles which represents local traffic and driving conditions.

The objective of this paper is to develop a driving cycle for passenger car and motorcycle for Chennai city. The use of real-world data ensures representativeness of the developed cycle to the field conditions. Consequently, the developed driving cycle can be used for emission testing of vehicles in the laboratory as well as an input into emission estimation models.

2. Methodology

2.1. Data collection

The on-road driving (speed-time) data was collected using GPS and on-board diagnostic (OBD) reader. On-board measurement technique was adopted instead of chase-car method, as it is difficult to follow a target vehicle in dense conditions prevailing in Indian traffic. The Garmin etrex 10 hand-held GPS device was used for this purpose. The second-by-second speed of the vehicle was recorded during each of the test runs.

The test vehicles chosen were a Tata Indica passenger car with a 1400 cm^3 diesel engine and manual transmission, and, a Bajaj Discover motorcycle with an engine capacity of 125 cm^3. Both the vehicles were under regular maintenance.

The test route chosen for the study consisted of a corridor of approximately 14 km in length around the IIT campus in South Chennai (Fig. 1). This route consists of four main arterial roads, namely, Sardar Patel Road (black), Velachery Main Road (yellow), Tharamani Link Road (green) and IT Corridor (brown). This route was chosen as it includes roads of all types (divided/undivided with different lane configurations) and hence representative of the arterial road network in Chennai. A total of eight round trips of the test route containing both GPS and OBD reader data were synthesized and compared for various vehicle operating modes.

The peak hour data was collected from 8:00 a.m. to 9:00 a.m. and 5:00 p.m. to 6:00 p.m. during the months from July to December 2015. The off-peak period was captured by collecting data in the afternoon between 1:00 p.m. and 2:00 p.m. Typically, the peak periods extend over a longer duration – 2–3 h - on these busy arterials. The peak hour over which we collected data (8–9 a.m. and 5–6 p.m.) is typically the starting part of this extended peak period. Taxis with professional drivers were employed to drive the passenger cars whereas regular motorcycle riders were employed in the case of motorcycles. The drivers varied during data collection. The data from motorcycle was collected only during the off-peak hour due to safety concerns as the rider had to carry a bulky load containing GPS receiver and a power source resting on the pillion seat of the vehicle.

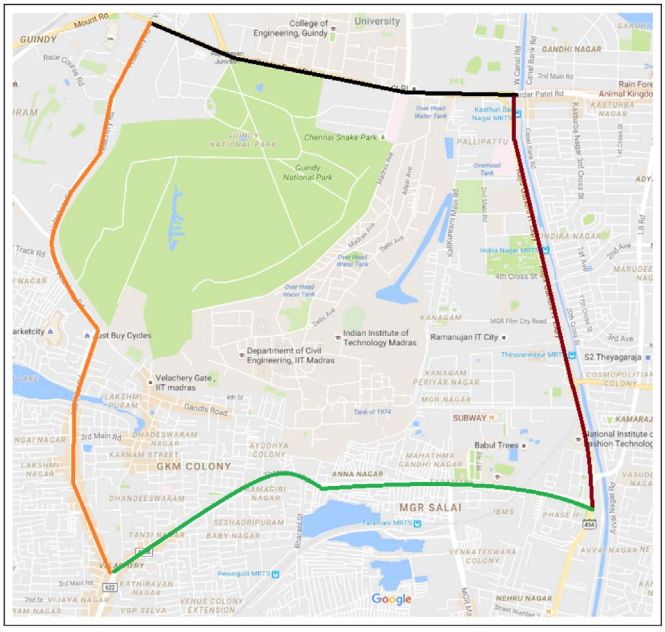

Fig. 1. Test route (Source: Google maps).

The different driving modes of the vehicle were defined as; idling (speed equals zero), cruising (speed > 5 kmph, acceleration < 0.1 m/s^2 and deceleration < 0.1 m/s^2), creeping (speed < 5 kmph, acceleration and deceleration < 0.1 m/s^2), deceleration (speed > 5 kmph and deceleration > 0.1 m/s^2) and acceleration (speed > 5 kmph and acceleration > 0.1 m/s^2).

2.2. Driving cycle development

Different parameters used to describe the driving characteristics were identified from the literature review (Amirjamshidi & Roorda, 2015; Ho et al., 2014; Kamble et al., 2009; Tong et al., 1999). The following parameters were finally chosen as assessment criteria:

(1) Average speed (V) – Average speed of entire trip (kmph)
(2) Average running speed (V_r) – Average speed of entire trip excluding idle time (kmph)