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A Critical Review on Direct And Indirect Influences of Driving Patterns of Public and Private Vehicles on Vehicular Exhaust Emission

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Abstract: Driving pattern of public vehicles are different than that of private vehicles. In mixed traffic condition, both private and public vehicles share the same same road width. Due to their difference in idling and maneuvering patterns they influence the driving patterns of each other. This complex interaction often leads to decreased average speed and increased travel time for both vehicle classes which eventually leads to increased vehicular emission.

Introduction

Easy and frequently available means of transportation is one of the most important needs for any civilization. Good transportation service increases collective efficiency of a society, better medical service and lower anxiety level of citizens. But this convenience comes with both positive and negative aspects. People, seeking more comfort are desirous to get the most out of technology and use it to such an extent that it poses threat on environment as well as on human health, especially in developing countries, where restriction on usage of those technologies and awareness on adverse effect of indiscriminate use of the same is lacking. Use of fossil fuel based vehicles is one of such technologies that need strict regulation in order to maintain healthy environment. Since 1942, India is continuing production of automobiles. Although in 90s, growth rate of vehicle production was only 9.4 percent per annum [1], from 2007 onwards growth rate increased significantly. Steep increment in vehicle production in India leads to a situation where the capacity of existing road facilities is reached, especially at peak hours, resulting a bottleneck condition and heavy traffic congestion. Due to increasing traffic delay, vehicles are gradually turning against their own purpose of existence, i.e., to save time. In addition people are being more exposed to harmful pollutants from automobile exhaust. As a result, vehicular pollution takes a huge toll on people residing near major roads. Besides

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pulmonary diseases, traffic emission produces more deadly consequences. It was found that residents of roadside apartments experience more exposure to hazardous pollutants like benzene, which is carcinogenic in nature and its exposure in ppmv level may cause leukemia [2]. Exposure of Nitrogen dioxide (NO_2) to women is associated with diabetes mellitus [3]. Women living within 50 meter from major roads has higher rate of Rheumatoid Arthritis [4]. Finklestein (2004) showed that people living close to major road network has increased risk of mortality [5]. Those who live away from busy roads spend considerable time in traffic environment too. Especially children and office employees are exposed to vehicular emission on their way to work. Traffic congestion makes it worse by extending their exposure time. Occupation specific exposure is also a matter of concern. Roadside shopkeepers and hawkers are subjects to continuous exposure of traffic pollution.

Relationship between driving pattern and vehicular emission

Vehicular emission is directly dependent on operating conditions such as, vehicle speed and acceleration [6], [7]. Detailed information on speed profile is required to estimate emission rate more precisely. From obtained speed information, distribution of time spent in different driving mode i.e. accelerating, decelerating, cruising mode. Idle time emission also contributes significantly in total emission [8]. Tsai (2003) demonstrated a clear distinction in emission rate of volatile organic carbon (VOC) among various driving modes [9]. The researchers selected 19 test motorcycles on the basis of the mileage and engine type to represent in-use motorcycles in Southern Taiwan. The test motorcycle samples included 7 new motorcycles and 12 in-use motorcycles. Eight 2-stroke and four 4-stroke in-use motorcycles, and four 2-stroke and three 4-stroke new motorcycles were chosen. The vehicle driving patterns in the metropolitan areas in Taiwan were found to be similar to those of the European driving cycle (ECE). One complete test cycle of 780 seconds was composed of idle period of 240 seconds, acceleration period of 168 seconds, cruising period of 228 seconds and deceleration period of 144 seconds. Dynamometer test was also done for the test vehicles using HORIBA, CVS-51S. The gas was analyzed for Carbon monoxide (CO), total hydrocarbon (THC), and oxides of nitrogen (NO_x) and premeasured background concentration was deducted to obtain accurate emission rate. Findings of this study showed that VOC emission is more in idle and deceleration mode than that of acceleration and cruising mode. Apart from driving modes, engine start mode is also an

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important factor to take into consideration while estimating traffic emission. Yang (2005) used ECE cycle to assess polycyclic aromatic hydrocarbon emissions from motorcycles in Taiwan city [10]. Researchers used HORIBA, CVS-51S for chassis dynamometer test. The study suggests that poly aromatic hydrocarbons (PAH) emission is more in case of cold-start driving that that of hot-start driving.

Macroscopic and microscopic approach

Average speed-based macroscopic emission models are unable to represent actual driving pattern and cannot account for acceleration, deceleration. These models may inaccurately estimate emission rates in congested traffic conditions in specific road segments and operating conditions [11]. On the other hand, microscopic models provide a more accurate estimate of vehicular emissions in congestion and other driving conditions. Microscopic models such as the Comprehensive Modal Emissions Model (CMEM) [12] and EPA Motor Vehicle Emission Simulator (MOVES) [13] has the capability to estimate emissions over a wide temporal range from second to hours, and for specific vehicles. Microscopic emission models use second by second speed profiles of test vehicles, which can be obtained with geographic positioning system (GPS) devices or speed sensor mounted on wheels.

Exclusiveness of real-world driving cycles

Driving cycle provides the knowledge of the duration and frequency of operating conditions. As many factors such as, population of vehicles, types of vehicle and their share in total vehicle count, frequency and duration of congestion, nature of the city and its prime working hours, road condition, width, average length etc. varies largely location to location, it is reasonable to assume that this variation will be reflected on the driving pattern and hence on emission. Moreover roadside environment, vehicle design, traffic characteristics and geometric design affect emission rate significantly [14], [15]. In India, most of the studies regarding vehicular emission estimation are done using emission factors from American and European studies [16], [17], [18]. European Transient Cycle (ETC) and European Stationary Cycle (ESC) are derived from real-world field measurement in European road networks. As the factors affecting the driving pattern are completely different from that of a developing country, the

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emissions will also likely to be different. Exclusive driving cycle may contribute as a correction factor to make the emission rate calculation more accurate.

Development of exclusive driving cycle

Location specific real-time driving cycles were developed for many cities around the world. Federal Highway Administration (FHWA) adopted a methodology to develop driving cycle based on the Kansas City emissions study performed by Eastern Research Group (ERG) for EPA [19]. A block diagram of the procedure is presented in Fig.1. Twelve driving cycles were constructed for inclusion in MOVES. At first, sampled raw speed data was prepared for further processing. Data preparation started with road type assignment. The road network under study was classified into 10 unique classes such as highways, local roads, major roads, minor roads etc. Next step in data preparation was to remove waiting time at the beginning or at the end of the trips or time spent at parking lot. Any duration where the speed recording was stuck at certain value due to the malfunctioning of the device, was also removed. False trips, i.e. trips with very short duration and very low speed, were removed. As engine stop time do not contribute to emission, duration of these period was also removed from the data set. A set of micro-trips were then generated and distributed into 12 bins according to their mean speed and road types. A micro-trip is a segment of running time of the vehicle of interest, enclosed with two idle periods. The speed and acceleration of each micro-trip was used to select the micro-trips which can represent the bin it falls in. each micro-trip then was converted into a speed/acceleration vector and target vectorwas derived by converting all of the micro-trips for that bin into the speed/acceleration. A computer program then found the micro-trip for which the sum of the squares of the cumulative normalized elements is closest to that of target vectors. Following this procedure, 25 micro-trips were added to form a cycle. The cycle generated this way was then fitted into MOVES model for estimation of emission.

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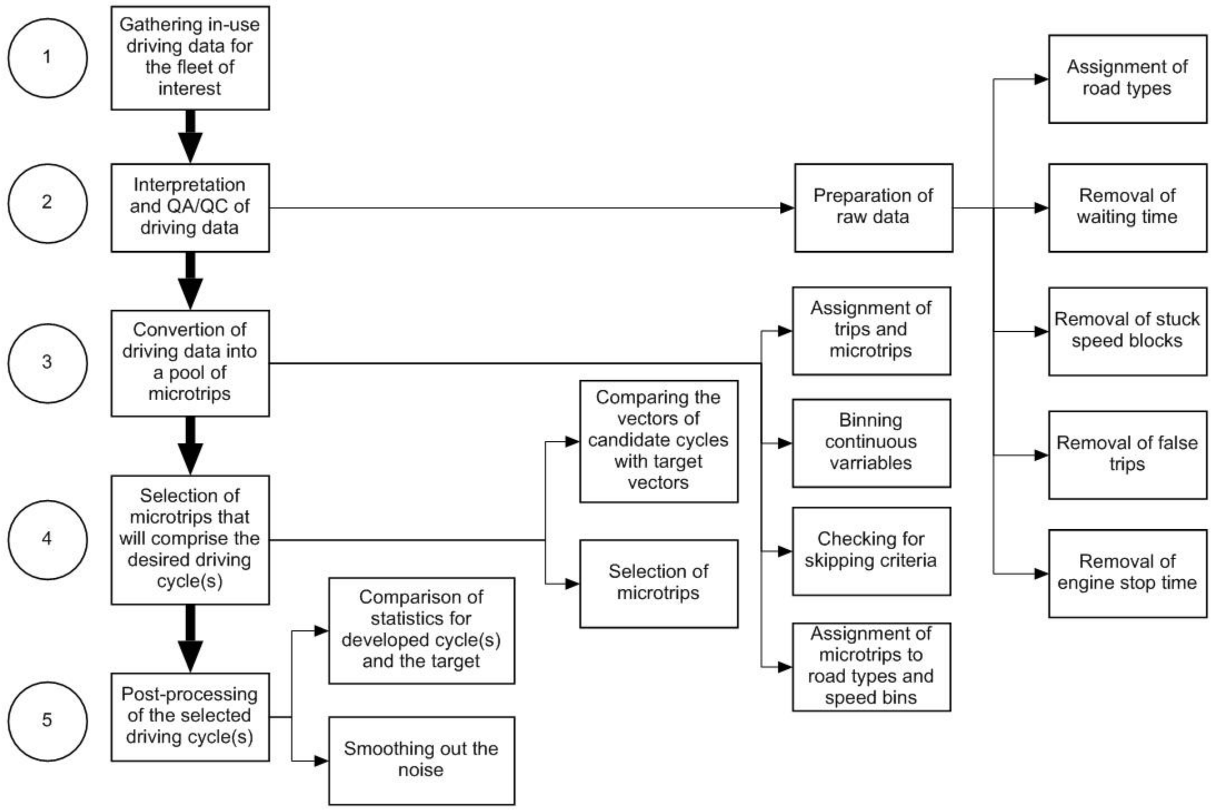

Fig.1: Block diagram of the procedure adapted by ERG for development of driving cycle based on Kansas City emission study (diagram is constructed on the basis of literature).

Chen (2003) adopted the motorcycle-to-motorcycle follow-up method using magnetic chips attached to the front wheel disk points 90° apart from each other [20]. The system was attached to a laptop via RS-232 port. Feeding the value of wheel diameter, speed profile was calculated. The study was carried out on total of 24 crossroads in three locations: Taipei (commercial and residential sites), Taichung (downtown and suburban sites) and Kaohsiung (commercial and industrial sites). Side by side, a dynamometer test of 2-stroke and 4-stroke motorcycles was also carried out in the laboratory to determine the emission factor (EF). The study established the connection between real-time driving patterns and emission level for both urban and rural areas under study. One of the conclusions of the research team was that as urban driving pattern differ from its rural counterpart because of the occurrence of congestion, traffic signals and intersections, fuel consumption and emission level also differ significantly.

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Nesamani (2011) developed a driving cycle for intra-city buses in Chennai, India [21]. Researchers selected 6 routes with length of 12-16 km and width 7-24 m. On-board measurement approach for data collection was adapted for this study. Selected buses were equipped with GPS to record speed data. Data collection was done on weekdays during morning peak (7:30-9:30 AM), afternoon non-peak (12:30-2:30 PM) and evening peak (5:00-7:30 PM). Each of the trips was of 70-120 minutes.

Chain of consequences: Indirect influences of driving pattern on environment

Besides the direct influences of driving pattern on vehicular emission and consequent impact on air quality, driving patterns of both public and private vehicles have immense indirect influence on each other. Public vehicles in India are often observed to pickup and drop passengers at non-designated stoppages on both highways and arterial road networks [22], [23]. As a result, the trajectories of the private vehicles following the public vehicles are affected and the average travel time of the private vehicles increases.

On the other hand, the rush driving of private vehicles often affects the speed profile of the public vehicles. Moreover, rush driving and jumping red signals may cause a chaotic situation in intersections which in turn can increase the travel times of the following vehicles. Road accidents due to the unpredictable driving patterns can also increase the travel duration. Asa consequence, the vehicular emission from both private and public vehicles increases. As the vehicular exhaust emission largely contains carbon dioxide, it can be stated that the aforementioned series of events ultimately increases the enhanced greenhouse effect and consequently contributes in global warming. Besides, the excess heat radiated from the engines of the vehicles due to long idle period contributes to urban heat island effect (Takebayashi, 2009) [24].

Conclusion

In order to reduce the intensity and frequency of traffic congestion, several traffic management policies have been implemented worldwide. Some of the most widely used and effective strategies are construction of mini roundabouts in suitable arterial roads [25], [26], well-defined stoppages for public vehicles [27], implementation smart traffic management system (Su, 2011) [28], micro-controller based highway speed checker, wireless rash driving detector etc. and

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construction of separate lanes for different vehicle classes. Although the aforementioned policies are significantly effective to reduce the traffic congestion and consequently the emission of greenhouse gases, the implementation of these policies, especially in developing countries like India is challenging and needs dedicated efforts from government, policy makers as well as from the mass.

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