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Real world vehicle emissions: Their correlation with driving parameters

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ABSTRACT

Vehicular population in developing countries is expected to proliferate in the coming decade, centred on Tier II and Tier III cities rather than large metropolis. WLTP is being introduced as a global instrument for emission regulation to reduce gap between standard test procedures and actual road conditions. This work aims at quantifying and discernment of the gap between WLTC and real-world conditions in an urban city in a developing country on the basis of driving cycle parameters and simulated emissions for gasoline fuelled light passenger cars. Real world driving patterns were recorded on different routes and varying traffic conditions using car-chasing technique integrated with GPS monitoring and speed sensors. Real-world driving patterns and ambient conditions were used to simulate emissions using International Vehicle Emissions model for average rate (g/km) and Comprehensive Modal Emissions Model for instantaneous emission (g/s) analysis. Cycle parameters were mathematically calculated to compare WLTC and road trips. The analyses revealed a large gap between WLTC and road conditions. CO emissions were predicted to be 155% higher than WLTC and HC and NOx emissions were estimated to be 63% and 64% higher respectively. These gaps were correlated to different driving cycle parameters. It was observed that road driving occurs at lower average speeds with higher frequency and magnitudes of accelerations. The positive kinetic energy required by road cycles, was 100% higher than WLTC and the Relative Positive Acceleration (RPA) demanded by road cycles, was found to be 60% higher in real-world driving patterns and thereby contribute to higher emissions.

Background and historical perspective

The share of the world's population living in cities will grow to nearly 70% by 2050 and energy consumption for transport needs in cities is expected to be much higher, which has already doubled in last 30 years (Dulac, 2012). The light duty vehicles will continue to drive the growth and currently consuming around 20% of the total oil consumed in transport sector (Dulac, 2012). The high fuel consumption and emissions affect the air quality and consequently the human health and environment. Poor ambient air quality (outdoor air pollution) in both cities and rural areas was estimated to cause 3.7 million premature deaths worldwide in 2012. People living in low- and middle-income countries disproportionately experience the

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burden of outdoor air pollution with 88% (of the 3.7 million premature deaths) occurring in low- and middle-income countries, including India, and the greatest burden in the world health organization (WHO) Western Pacific and South-East Asia regions (WHO, 2014).

Vehicle emission standards are the primary technical policy tools available for mitigating emissions from vehicles. The emission test procedures for the light duty vehicles are based on a transient cycle representing driving pattern of a particular country. The light duty vehicle cycles FTP-75 and NEDC are used in US emission and European test procedures, respectively. The China and India are following the NEDC for light duty vehicle emission measurements. The real world driving pattern is a highly dynamic process and it was found during early 1990s that the FTP-75 test cycle does not cover even more than 15% of driving conditions and behaviour encountered in real life operation such as aggressive driving and driving immediately after cold start. So, the development of a real-world driving cycle is important for traffic and transport management, on road vehicular fuel consumption and emission reductions (Andre, 1996; Bata et al., 1994). Various countries have developed driving cycles to analyse different aspects and impacts of local driving conditions, as summarised in Table 1.

These studies bring out the significant difference between certification cycle and real world driving cycle in terms of key driving parameters. The driving cycle is the main parameter for emission testing of light duty vehicles and the deviation from the certification cycle may be the pre-dominant cause for gap between real world fuel economy and type approval data.

Some studies have been carried out, specifically, to assess the gap between certification and real world fuel economy and emissions. The 5th Framework Programme of the European Commission under DECADE project, using intensive measurements on engine dynamometers, chassis dynamometers and in real traffic experiments have established that most of the emissions measured in the certification cycle differed dramatically from the real traffic emissions. (Pelkmans and Debal, 2006; Joumard et al., 2000) carried out a study to understand the influence of driving cycles on unit emissions from passenger cars by considering petrol engines and diesel cars and concluded that as compared to representative cycles, the standardised cycles underestimate hot emissions by almost 50% for petrol engine cars and 30% for diesel vehicles. A recent ICCT study (Franco et al., 2014) compared emission of diesel cars on road with Euro VI limits and certification testing. The study concluded that modern diesel passenger cars have low on-road emissions of carbonmonoxide (CO) and total hydrocarbons (THC), but an unsatisfactory real-world emission profile of nitrogen oxides (NOx). The average, on-road emission levels of NOx were estimated at 7 times the certified emission limit for Euro 6 vehicles.

In India, the Indian Driving Cycle (IDC) was developed in 1985 (Kamble et al., 2009).Further important studies were undertaken consequently (Badusha and Ghosh, 1999; Nesamani and Subramanian, 2011; Anand et al., 2005; Kamble et al., 2009; Grieshop and Boland, 2012). These studies mainly focussed on the methodology of data collection of the real world driving and development of the driving cycle for different category of vehicles. However, few of them reported the difference between real world fuel economy and emission as compared to certification data. A study (Nesamani and Subramanian, 2011) carried out in Chennai revealed that Indian driving cycle does not represent real world driving and emissions were estimated almost two times higher in real world as compared to predictions by IDC. A study (Grieshop and Boland, 2012) on auto rickshaws running in Delhi assessed whether the IDC, used for emission factor development in India, accurately represents emissions from on-road driving or not. The result showed that the IDC systematically under-estimates fuel consumption and emissions; Real-world auto-rickshaws consume approximately 15% more fuel and emit around 49% more THC and contribute 16% more to PM2.5. A study on real-world fuel economy (Pathak et al., 2010) on Dehradun–Delhi highway and Delhi–Jaipur highway concluded that the real world fuel economy in two different highways were significantly different from certification values. The data from the study also established that current practice underestimates the emission rates as compared to complex real world driving conditions.

The studies as mentioned above concluded that for most of the categories of vehicles, average emissions during real world conditions are higher than their average emissions on a standard driving cycle. This may be due to the fact that the standard cycle is generally considered, representing mild driving condition while the real-world driving situations are more dynamic and harsh.

Table 1
Research on driving cycles across the world.

Country	Researcher	Aim
China	Wang et al. (2008a, 2008b)	Driving cycle development and comparison with European and US cycles
Canada	Seers et al. (2015)	Development of two driving cycles for utility vehicles
UK, South Korea	Birell et al. (2014)	Analysis of three independent real-world driving studies
South Korea	Han et al. (2012)	Characterization of driving patterns and development of a driving cycle in a military area
UK	Kumar et al. (2011)	Comparison and evaluation of emissions for different driving cycles of motorcycles
China	Tong et al. (2011)	Development of driving cycles for motorcycles and light-duty vehicles in Vietnam
Vietnam	Tung et al. (2011)	Development of emission factors and emission inventories for motorcycles and light duty vehicles in the urban region
China	Peng et al. (2015)	Construction of engine emission test driving cycle of city transit buses
India	Nesamani and Subramanian (2011)	Development of driving cycle for intra city buses