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Development of two driving cycles for utility vehicles

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ABSTRACT

Driving cycles are used to assess vehicle fuel consumption and pollutant emissions. The premise in this article is that suburban road-work vehicles and airport vehicles operate under particular conditions that are not taken into account by conventional driving cycles. Thus, experimental data were acquired from two pickup trucks representing both vehicle fleets that were equipped with a data logger. Based on experimental data, the suburban road-work vehicle showed a mixed driving behavior of high and low speed with occasional long periods of idling. In the airport environment, however, the driving conditions were restricted to airport grounds but were characterized by many accelerations and few high speeds. Based on these measurements, microtrips were defined and two driving cycles proposed. Fuel consumption and pollutant emissions were then measured for both cycles and compared to the FTP-75 and HWFCT cycles, which revealed a major difference: at least a 31% increase in fuel consumption over FTP-75. This increased fuel consumption translates into higher pollutant emissions. When CO_2 equivalent emissions are taken into account, the proposed cycles show an increase of at least 31% over FTP-75 and illustrate the importance of quantifying fleet speed patterns to assess CO_2 equivalent emissions so that the fleet manager can determine potential gains in energy or increased pollutant emissions.

Introduction

A wide variety of standard driving cycles are used to implement state emission regulations. The US FTP-75 and SFTP procedures, the soon-to-be-replaced European NEDC series, and the new Japanese JC08 cycle are among the best known. Standard driving cycles, however, are generic and may not be consistent with local network specifics, such as topography, topology, traffic, and driver behavior. When accurate small-scale emission rates have to be determined, specific driving cycles are developed to take into account local and particular conditions that may significantly influence emission levels. Many specific driving cycles have been proposed recently for Hong Kong (Hung et al., 2007), Pune (Kamble et al., 2009), Bangkok (Tamsanya et al., 2009), Mexico City (Schifter et al., 2005), Edinburgh (Saleh et al., 2009), just to name a few. Their singularities are proof of the diversity of urban road networks and driving behavior. Since vehicle fuel consumption and emissions are influenced by operating conditions (Wang et al., 2008; Booth et al., 2001), specific driving cycles are needed to sketch a portrait of fuel consumption and atmospheric emissions caused by fleets of vehicles. Furthermore, specific driving cycles may help in assessing a fleet's impact on air quality and greenhouse-gas emissions, if modeled (Grieshop et al., 2012), or to assess well-to-tank energy consumption, as was recently proposed (Ma et al., 2011).

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This paper originated out of the need to assess the fuel consumption and CO_2 equivalent emissions of two different fleets of pickup trucks. The first fleet—owned by the town of Salaberry-de-Valleyfield (SdV)—is used to transport workers and equipment in a suburban environment in Montréal, Canada. The second fleet consists of pickup trucks, but their use is confined exclusively to within the limits of Pierre Elliot Trudeau International Airport (PETIA), located in Montréal, Canada. It was determined that assessing the respective fleet fuel consumption and CO_2 emissions meant acquiring a driving pattern representative of each fleet, which would then be compared to known driving cycles. The main objective of this paper is to use this comparison to propose two driving cycles for estimating the fuel consumption and emissions of both fleets. The paper is constructed as follows: First, the methodology used to acquire experimental data and its post-treatment are defined. The main driving characteristics of each fleet of vehicle are analyzed and compared to known driving cycles. Lastly, the proposed driving cycles are presented and discussed; the fuel consumption and pollutant emission results are also presented.

Methodology

A pickup truck (Ford F-150, 2010) belonging to Salaberry-de-Valleyfield (SdV) and one from the Pierre-Elliot Trudeau International airport (PETIA) were instrumented in order to determine driving characteristics and develop driving cycles. The PETIA vehicle is operated within the confines of the airport grounds not connected to public roads. The SdV vehicle is used to carry workers and equipment around Salaberry-de-Valleyfield, mostly in suburban areas and occasionally on highways. Both vehicles serve for specific applications that entail non-standard driving behaviors, which is the premise of this study. A complete methodology was designed to develop a driving cycle specific to each use. The three main steps of this methodology are presented briefly below.

Data collection

In the literature, car-chasing (see Hung et al., 2005, for example) and on-board (Saleh et al., 2009; Tamsanya et al., 2009 to name a few) measurements are used to collect vehicle speed over time. Herein on-board data acquisition was used for eight weeks on the PETIA vehicle and for six weeks on the SdV vehicle. An ISAAC DRU-800 data logger was connected to the vehicle's OBD-II port and was configured to record instant wheel speed at a rate of 1 Hz whenever the engine was running. The data logger was installed and acquisition initiated without the driver's knowledge. This element, combined with the relatively long acquisition period and the fact that the drivers were under no particular restrictions, made it possible to capture true driver behavior. At the end of the acquisition period, the data were downloaded to a computer for analysis.

Data processing

After collection, the data were transferred and posttreated in MATLAB R2009b with code developed in-house. The first step in the data posttreatment was characterizing and calculating the vehicles' different indicators, such as average speed, maximum speed, and acceleration, as presented in Table 1. These indicators are similar to those used by Saleh et al. (2009), Hung et al. (2007), and Lin and Niemeier (2003). In Table 1, the terms v and α, respectively, refer to vehicle instant speed and acceleration rates. Herein, the vehicle is considered to be accelerating when its speed is greater than 5 km/h such as Hung et al. (2007) and Amirjamshidi and Roorda (2015) and its α is higher than 1 m/s^2 as to obtain the same acceleration resolution than Hung et al. (2007).

A set of five indicators focus on the distribution of five operating modes, namely, idling, accelerating, decelerating, cruising, and creeping. Positive kinetic energy (PKE) was used as a measure of aggressiveness (Lin and Niemeier, 2003). PKE expresses an average acceleration value; the average work performed by the engine per distance covered to provide

Table 1
Indicators for road-behavior characterization.

Indicator	Definition
Average speed	Total covered distance/total recorded time
Maximum speed	Maximum recorded speed
Operating-mode distribution	
Idling	$v = 0$
Accelerating	$\alpha > 1$ m/s^2 $v > 5$ km/h
Decelerating	$\alpha < -1$ m/s^2 $v > 5$ km/h
Cruising	$\alpha \in [-1;1]$ m/s^2 $v > 5$ km/h
Creeping	$v \in]0;5]$ km/h
Positive kinetic energy (PKE)	$\mathrm{PKE} = \frac{1}{D}\sum_{i=1}^{n-1}\left(v_{i+1}^2 - v_i^2\right) \quad \forall\ v_{i+1} > v_i$
SAFD matrix	Matrix of speed–acceleration frequency distribution with 5 km/h and 1 m/s^2 increments, respectively