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Driving cycle developments and their impacts on energy consumption of transportation

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ABSTRACT

One of the most significant current discussions in climate change is around the issue of low carbon emission and its effect on human health. It is becoming increasingly difficult to ignore the transport share of world emissions. Recent developments in this field have heightened the need for Driving Cycle establishment in order to understand and reduce vehicle emissions. However, a major problem with this Driving Cycle characteristic is that it varies from one city to another due to the type of principle activities (industrial, agricultural) present. Therefore, individual testing is necessary for each region in order to establish a representative tool for Local Authorities to identify the air quality in terms of traffic emissions.

To date, there has been little discussion about Driving Cycle developments, so in this paper, experimental studies, which predict sufficient parameters in driving cycle modelling, were summarized in the literature review and gave comprehensive feedback to the field for further investigations. Subsequently, the author presented a simple method for establishing the driving cycle, and estimating vehicle emission. As COPERT software is one of the most commonly deployed tools in Europe, the methodology involved a formula that is being obtained from COPERT. Later this formula is being used in a program which makes use of bulk traffic movements and average vehicle speeds in order to estimate emissions. The combination of On-board diagnostic data extraction incorporated in all modern passenger cars and program used to allow real world vehicular activities to be recorded, in order to better estimate the contribution of private cars to local emissions inventories. Representative driving cycles reflecting the real-world driving conditions of two cities were proposed and estimated vehicle emissions were compared with measured results.

1. Introduction

A “driving cycle” is a time series of vehicle speeds developed to represent typical driving patterns. They are used intensively in estimating vehicle emissions, computing energy consumption, and assessing traffic impact. So far, there is no existing driving cycle officially developed to represent traffic in Ireland. Local authorities relied primarily on the European test cycle (ECE) and the New European Driving Cycle (NEDC) to generate the emission factors and the national inventories. In the opinion of the authors, this may not be able to produce accurate results because driving characteristics differ from one area to another. In fact, many studies have been conducted in China (Wang et al., 2008; Cai and Xie, 2007) to identify the differences in vehicle driving patterns between the real situation in China and the standard cycles in other countries. As social, economical, and geographical features vary dramatically throughout the country, the variation in driving patterns in different cities could be significant. China is facing serious air pollution problems, with a large contribution from vehicle emissions (Cai and Xie, 2007).

Many modelling methods have been developed in estimating the emission factors in the transport sector (Latham et al., 2000; Düring et al., 2005). National emissions inventories in areas (such as a country or a state) are important to assess the emissions levels, identify the air quality and help reduce the hazardous emissions affecting human health and environment. Studies have been done in developing these modelling methods to estimate the emission factors CO, CO_2, HC, NOx and PM (Latham et al., 2000). This study also investigated other factors such as evaporative emissions and

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PM emissions of brake dust (Düring et al., 2005). The standard modelling method in Europe and the US is the average-speed models, and the most useful data set for the work carried out for the research in Europe is COPERT (Computer Programme to estimate Emissions from Road Transport) (Ntziachristos and Samaras, 2000) or the TRL (Transport Research Laboratory) emissions factors. Both can describe emissions in terms of grams per kilometre travelled [g/km] and are functions of vehicle speed (Edward and Bright, 2008), such that for the TRL factors:

$$EF_{i,m,n} = k + ax + bx^2 + cx^3 + \frac{d}{x} + \frac{e}{x^2} + \frac{f}{x^3} \quad (1)$$

where a, b, c, d, e, f and k are coefficients specific to a given engine size m and technology level n, x is the average vehicle speed in kilometre per hour (km/h), $EF_{i,m,n}$ is the emission value, in grams per kilometre travelled (g/km) for a given species i, of age n and engine size, m.

Emissions calculations exist for each of carbon dioxide (CO_2), carbon monoxide (CO), particulate matter (PM), oxides of nitrogen (NOx) and unburned hydrocarbons (HC) (Samuel et al., 2002). A similar equation exists for the COPERT model and it will be discussed later in this paper. Validation studies for COPERT as well as method comparison studies are still on-going. Ekström et al. (2004) found an agreement in NOx emissions between COPERT and on-road sensing measurements, while a weaker agreement was noticed for CO and HC (with COPERT, this was overestimated). Another programme (MOBILE6) has been compared with on-road sensing measurements. Here noticeable differences were found between the two methods; the modelled values are 30–70% higher, 40% lower and 40–80% higher than the calculated CO, HC and NO values, respectively (Pokharel et al., 2002). Smit et al. (2007) introduced a new modelling approach for road traffic emissions (VERSIT+), when compared to COPERT; a higher accuracy was noticed with (VERSIT+) with respect to emission estimations. Although average-speed models have a world-wide use in transport sector, there are some difficulties facing this method. These include fleet test data, fleet activity patterns, acceleration issues and identification of local emissions (North, 2006). However, good correlations between the predicted results of the modelling packages and the actual data obtained by direct measurement are still maintained.

The conventional measuring of vehicular emissions involves driving a vehicle through a pre-determined Driving Cycle on a rolling road dynamometer and collecting the pollutant emissions formed (André, 2004; Guibet, 1999). These emissions are analysed, then a system is devised so each value for emission output is assigned to each section of the Driving cycle. This normally results in a value for the mass of the pollutant species evolved over a given distance ($g\,km^{-1}$). Other methods are on-road emission monitoring techniques which are usually divided into two types of emission tests:

1. *Monitoring equipment*: used to measure the emission concentrations in ambient air (Fuller, 2006). This type of technique uses a pump to sample the ambient air and sometimes samples of PM or HC emissions collected and analysed in a laboratory (Harrison et al., 2003), and it is considered to be a good tool in measuring the in-use vehicle fleet rather than single vehicles measurements (Shi et al., 2002). One of their applications has been applied in tunnel studies, where this equipment is placed inside the tunnel in order to measure the emissions factors for CO, CO_2, NOx, and HC (Hausberger et al., 2003). Sometimes, tunnel studies have been conducted in order to validate the emission estimations (Fuller, 2006).
2. *On-road remote sensing*: used where some tools is set up on a roadside to measure the emissions from a single car when it passes (Environment, 2010). These tools have been developed by researchers for a better understanding of emission factors of CO, NO, HC and PM (Bishop and Stedman, 1996), some studies visualized number of significant findings with respect to the methodology used such as consistency and accuracy in measuring the vehicle emissions (Jimenez et al., 1999; Moosmuller et al., 2003). On-road remote sensing was successfully used in many regions to specify vehicle fleet emissions such as in Monterrey, Nuevo Leon, Mexico (Bishop et al., 1997), in the Denver metropolitan area (Bradley et al., 2000), and in California, 1991 and in Michigan, 1992 (Stephens et al., 1997). Fuel consumption has been improved for emissions factors using this technique (Pokharel et al., 2002). However, there is no direct method to determine the details of the mode of operation such as gear, engine speed, etc. at the moment of measurement and this is one of the issues facing the challenge of measuring real world emission factor (Wenzel et al., 2000).

Estimating emissions are achieved by either scaling the European Union legislative emissions values or by employing aggregated fleet emissions models, such as COPERT or TRMOVE. Such models require a variety of data including fleet composition, fleet age, distances travelled by each vehicle type in a given year and meteorological data. All of these values are averaged, so it does not adequately describe the localized situations in different cities and towns. Twenty two countries within the European member states (EU27) use the model COPERT for the official data of road transport inventories for international conventions (Pouliot et al., 2012). COPERT has been developed to estimate the annual national inventory. It is non-commercial and can be used by researchers for academic purposes. COPERT can be applied on segments and small regions (Sharad, 2012). The software also gives a comprehensive understanding of public transport use when compared to private cars (Giannouli et al., 2011). Therefore, one of the advantages of this software is that it can be used outside Europe, such as China (Wang et al., 2008; Cai and Xie, 2007), and specifically in Beijing (Su et al., 2011).

In Athens (Greece), fuel consumption and emission factors have been investigated on a chassis dynamometer using the new European driving cycle (NEDC) (Giakoumis and Lioutas, 2010) and the non-legislated Athens driving cycle (ADC) which consists of 16 phases of various durations, Fig. 1. Idle periods include a large proportion of the overall cycle time, whereas cruising time is just non-existent and the vigorous changes in travelling speed describe the aggressive behavioural conditions under which passenger cars are driven in the specific city (Karavalakis et al., 2007, 2009). The preferred distance for a cold start that vehicles cover in Athens, is equal to 6.9 km for urban areas (Tzirakis et al., 2007; Karavalakis et al., 2009). The first driving cycle was established in 2002 and developed post 2004.

In Edinburgh, the driving cycle for the urban area was developed from recorded data in actual traffic conditions between year 1998 and 2000 using the car chassis technique, Fig. 2, achieving the final production of Edinburgh driving cycle (Esteves-Booth et al., 2001). In 2009, “the Edinburgh motorcycle driving cycle” was developed following forty five trips on five routes around city centre (Saleh et al., 2009). An increase in cycle times was found compared to ECE, WMTC, and EDC driving cycles, which lead to a noted difference in driving conditions for motorcycles compared those for other vehicles (Kumar et al., 2011).

In Italy, a real driving cycle was used for the comparison of energy consumption between two different types of fuels. The