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# Development of Malaysian urban drive cycle using vehicle and engine parameters

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ABSTRACT

Vehicles travelling in actual urban areas are mostly in idle, low or medium speeds, which reflects engine part-load condition. These regularly visited engine conditions, in reality affect the fuel economy during actual driving. Thus, understanding the characteristics of the actual driving conditions will enable many other benefits besides legislation. This paper presents the development of a preliminary Malaysian urban drive cycle with the inclusion of the engine parameters and characteristics, acquired through an actual urban driving on numerous urban roads in Malaysia that represents the actual consumer's daily driving experience. The actual engine parameters and its characteristics are integrated into the assessment measures in an attempt to formulate representable drive cycle and fuel consumption data. The initial drive cycle is composed of 17 sequences selected from the actual on-the-road conditions to represent the Malaysian urban driving. The average fuel economy of the established Malaysian urban drive cycle was then measured on a test bench using the same engine from the vehicle. The recorded fuel economy with Malaysian urban drive cycle is 8.5% below the actual Malaysian urban driving which is closer estimation to the actual driving compared to the current in-practice NEDC which shows to be 43.1% below the actual Malaysian urban driving. Thus, Malaysian urban drive cycle is better in representing the Malaysian urban driving conditions compared to the NEDC in terms of the average fuel economy measurements.

## 1. Introduction

Vehicle drive cycles are developed to represent the actual driving over an intended area. Generally, the well-known drive cycles such as the WLTC (Worldwide harmonized Light vehicle Test Cycle), NEDC (New European Drive Cycle), FTP (Federal Test Procedure) and Japanese modes were seen originated from Europe, United States, Japan, China and India which are significant in the global automotive industry. Nevertheless there are also other areas that developed local drive cycles such as Hong Kong (Hung et al., 2007), Iran (Fotouhi and Montazeri-Gh, 2013) and Singapore (Ho et al., 2014). Drive cycles are commonly used in legislation by governing bodies in the effort to control the emission and fuel consumption. Drive cycles are also used by vehicle manufacturers and automotive suppliers for product evaluation purposes. In Malaysia, NEDC is still being used by the local authorities for legislation purposes and by the local manufacturers and suppliers for evaluation purposes. Even with the transition to WLTC, the need for a local drive cycle is mainly to contribute towards accurate fuel consumption assessments for Malaysian actual driving.

A B-segment sedan vehicle powered by a 1.6 L 4-cylinder PFI (Port Fuel Injection) gasoline engine with CVT (Continuous Variable Transmission) was initially tested to compare the fuel economy between the NEDC and the Malaysian actual urban driving. The

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mileage of the test vehicle has reached 10,210 km, driven passed through the 3000 km running-in period suggested by the Directive 70/220/EEC/Regulation No. 83-06, prior to conduct the NEDC test. Meanwhile the actual driving test was conducted based on the methodology as discussed in Abas et al. (2014). The fuel economy from the NEDC test was 8.06 L/100 km, while the actual Malaysian urban driving recorded 14.17 L/100 km (Abas et al., 2015). The NEDC average fuel economy is 43.1% below the actual driving, which led to in misconception by the local manufacturers during the development phase and more critically misleading information for consumers. The significant discrepancy in the NEDC average fuel economy has motivated this study to establish a local drive cycle that will demonstrate the actual driving condition, particularly in Malaysian urban areas.

This paper addresses the inclusion of engine parameters (engine speed and torque) into the assessment measures along with vehicle parameters (vehicle speed and acceleration based parameters) towards improving the accuracy in fuel economy measurements. As the fuel consumption is highly related to the engine conditions, inclusion of the actual engine variables minimizes discrepancies in the fuel consumption assessments against the actual driving.

## 2. Literature review

According to Xiao et al. (2012), the usual procedure in drive cycle development consist of data collection, generation of microtrips and followed by selection of assessment measures. The data collection involves vehicle testing on selected actual roads to collecting driving activity data. The data is then separated into small trips by grouping them into vehicle speed envelope, as traced between two successive stops (André et al., 1994). The assessment measures are the performance of the selected parameters - which are related to vehicle speed and acceleration, operational time, number of stops and its dynamic behaviour. Majority of the parameters used in the assessment measures are vehicle speed, acceleration and fragment of the driving (Xiao et al., 2012). Based on the literature review, none of the previous studies (Chugh et al., 2012; Xiao et al., 2012; Andre et al., 2009; Prasad et al., 2012; BARLOW et al., 2009; André et al., 2006; André, 2004) have included engine related parameters, specifically the engine torque and speed as the assessment measures. Representative fuel consumption is one of the main criteria in establishment of driving conditions within the area of study. Thus consideration of engine parameters is essential, as fuel consumption is strongly related to the engine load and speed.

In 2013, the Tehran driving cycle by Fotouhi and Montazeri-Gh (2013) was developed by using microtrips and the application of k-means method to cluster the sequences. The average vehicle speed and the percentage of idle time were used as the variables in the assessment measures. Clustering of the sequences leads to the identification of four traffic conditions; congested, urban, extra urban and highway driving. The Tehran driving cycle has characterised in terms of distance over 14.4 km, duration of 1533 s, average speed of 33.84 km/h and 15.3% of idling time.

Delhi driving cycle published in 2012 by Chugh et al. (2012) was developed using microtrips and the application of speed-acceleration frequency matrix formed by each of the sequence. The vehicle variables used for the assessment measures were average speed, percentage of idle time, percentage of acceleration/deceleration and percentage of cruising time. The microtrips were then clustered according to the known traffic conditions in Delhi – congested, semi urban, urban and extra urban driving. The ideal representative sequences for the drive cycle were selected based on the closest characteristics to the criteria of the traffic condition category it belongs to. The Delhi driving cycle has characteristics of 7.8 km in distance, duration of 1565 s, average speed of 25.5 km/h and 29.9% of idling time.

Shi et al. (2011) constructed driving cycle based on Markov process which is a stochastic process theory instead of short trips. The process uses transition matrix of the vehicle data and determine the statistical characteristics. Modal events are randomly selected from the data and combined until it reached the desired cycle length.

A case study in Pune India by Kamble et al. (2009), uses the microtrips from the vehicle data collected from an actual driving. The driving cycle was constructed using five time-speed profile parameters – percentage of acceleration, percentage of deceleration, idling, cruising and average vehicle speed. The development of driving cycle involves analysis using the vehicle speed and acceleration parameters as the frequency and normalised matrices on both the collected data and microtrips.

Besides the common microtrips method, new processes are constantly emerging and complimenting the existing method in improving the representativeness of the driving cycles. Even though there are varying methods to develop drive cycles, there are certain common steps in all of their procedures. The work presented in this paper aims to provide an alternative perspective in the selection of assessment measures. The engine speed and torque were used as the additional parameters, on top of the conventional vehicle parameters, in constructing the driving cycle. Furthermore, a Two-Step clustering method provided by IBM's SPSS (Statistical Package for the Social Sciences) software is applied in recognising the characteristics during the actual driving.

## 3. Methodology

The Malaysian urban drive cycle was developed according to the processes shown in Fig. 1. To establish a genuine sampling that represents actual driving, observations on the traffic within Kuala Lumpur urban district was conducted to select the test routes for the data collection. Live traffic congestion within the area of study was periodically observed using Google Map which plots live traffic sites base on crowdsourcing. Five routes with the worst traffic during peak hours were selected to represent the typical urban driving condition in Malaysia. The actual driving data collection was conducted over the selected routes during the peak hours using an instrumented passenger car to record the vehicle and engine operating parameters. The collected data was then processed by breaking the recorded trips into smaller trips known as microtrip. The vehicle and engine parameters were then simplified through principal component analysis and followed by clustering the data using TwoStep technique. The means of the generated clusters were used as the target criterion in selecting eligible microtrips as the sub-cycles. The sub-cycles were then arranged and constructed as the