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Methodology for kinematic cycle characterization of vehicles with fixed routes in urban areas

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ABSTRACT

This paper analyses the driving cycles of a fleet of vehicles with predetermined urban itineraries. Most driving cycles developed for such type of vehicles do not properly address variability among itineraries. Here we develop a polygonal driving cycle that assesses each group of related routes, based on microscopic parameters. It measures the kinematic cycles of the routes traveled by the vehicle fleet, segments cycles into micro-cycles, and characterizes their properties, groups them into clusters with homogeneous kinematic characteristics within their specific micro-cycles, and constructs a standard cycle for each cluster. The process is used to study public bus operations in Madrid.

1. Introduction

This paper analyses the driving cycles of a vehicle fleet with predetermined urban itineraries. Over the years, driving cycles have been developed in many ways, often to meet data and experimental constraints, but sometimes to address particular issues. Most have limitations. At present, for example, the Economic Commission for Europe proposal is a linearized cycle, with its urban component developed in accordance with the traffic patterns of Paris in 1992, but this both needs augmenting to allow for extra-urban traffic and is limited by the assumption of a very smooth acceleration profile (Pelkmans and Debal, 2006). The US cycle FTP72 (LA-4) was designed to reproduce the conditions of traffic in the city of Los Angeles and is used in the US for vehicle emissions certification, which additionally requires passing trials involving aggressive driving conditions and circulation with air conditioning. The Highway Fuel Economy Cycle was developed to evaluate fuel consumption and emissions in nearly stationary highway traffic conditions. The list of cycles is long, and Table 1 offers a list of some that have been developed with an indication of their context.

The diversity of cycles poses problems in the selection of appropriate options in different contexts. Here we develop a methodology for the construction of polygonal driving cycles that reproduce the operation of vehicle fleets traveling fixed urban routes, while discriminating between differences in itineraries, seeking an approach that is easily replicated in a test bench.

2. Methodology

Following André (2004) we construct kinematic cycles that allow recording of driving conditions, analyses of the data and the development of the cycle, by applying the following sequence:

- Measurement of the kinematic cycles in the routes traveled by the vehicle fleet.

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Table 1
Some relevant driving cycles.

Criterion		References
Specific region	Sydney	Kent et al. (1978)
	Japan 10-mode and 11-mode cycles	Kuhler and Karstens (1978)
	Seoul 14-mode cycle	Sun et al. (1989)
	Madrid	Casanova et al. (2001)
	Edinburgh	Esteves-Booth et al. (2001)
	Hong Kong	Hung et al. (2007)
	China	Wang et al. (2008)
Specific vehicle type	Urban buses	Terrón (1990)
		van de Weijer et al. (1993)
		Nylund et al. (2004)
		André et al. (2005)
		Gómez (2005)
	Refuse trucks	Bradley and Associates, Inc. (2005)
		Dembski et al. (2005)
		Ivani (2007)
		López et al. (2008)
	Sweeper	Bradley and Associates, Inc. (2005)
	Local delivery trucks	Clark et al. (1999)
		Nine et al. (1999)
	Motorcycles	Tzeng and Chen (1998)
		Saleh et al. (2009)
	Military vehicles	Han et al. (2012)

- Segmentation of the cycles in micro-cycles and characterization of their properties.
- Grouping of the routes into clusters with homogeneous kinematic characteristics within their specific micro-cycles.
- Construction of the corresponding cycle for each cluster of routes.

The methodology is applied to a bus routes in the city of Madrid, Spain.

Standard kinematic cycles are defined by the evolution of speed with respect to time, with the operating cycle divided into motion and stationary periods. In the data recordings, a micro-cycle corresponds to the evolution of the speed between two consecutive stops.

To obtain polygonal cycles, continuous recordings are categorized into micro-cycles composed of segments with constant acceleration, speed and deceleration to eliminate some oscillations from the original register. Movement micro-cycles with very low speeds and short durations are also discarded. While the only relevant information for stationary periods is their duration, the study of motion micro-cycles involves the utilization of the variables in Table 2. In addition, Table 3 illustrates the classification of the polygonal micro-cycles into the diverse typologies found by linking sections in acceleration, constant speed and deceleration.

Route clustering is necessary to reflect that routes are unlikely to have similar kinematic characteristics, that a single polygonal cycle will not reproduce all itineraries, and that there are groups of routes with similar characteristics. André and Villanova (2004) group buses by operational peculiarities: route characteristics, travel time, irregularity of the journey,

Table 2
Variables analyzed in a micro-cycle.

Variable	Units	Symbol
Global		
Duration	s	t_mean
Average speed of the micro-cycle	km/h	Vmean
Maximum speed in the micro-cycle	km/h	Vmax
Acceleration		
Duration of the initial acceleration	s	t_ac1
Duration of the micro-cycle in acceleration	s	t_ttl_ac
Initial acceleration in the micro-cycle	m/s^2	ac1
Constant speed		
Duration of the last section at constant speed	s	t_crul
Duration of the micro-cycle at constant speed	s	t_ttl_cru
Velocity during last section at constant speed	km/h	Vcru
Deceleration		
Duration of the final deceleration	s	t_decl
Duration of the micro-cycle in deceleration	s	t_ttl_dec
Final deceleration in the micro-cycle	m/s^2	decl