

## Using on-board logging devices for micro-monitoring energy efficiency of urban and suburban bus operation: the case of Rodoviária de Lisboa

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### Abstract

Air quality problems abound in urban areas and evidence suggests strongly that climate change is being induced by anthropogenic carbon emissions. Increasing transit share is one key solution to reduce energy and environmental burdens. Still, buses can also play their role and contribute to provide a more sustainable urban transport system. On the other hand, energy efficiency is a keystone in the management of bus operators, since energy consumption corresponds to a significant share of the companies' overall costs. Since the majority of buses have diesel powertrains, energy costs are aggravated by the increasing trend of fuel prices. Concomitantly, energy intensive companies are subject to energy management systems and corresponding plans for improvement. In this sense, there are several paths to increase energy efficiency and reduce energy costs of bus fleets: introducing more efficient technologies, shifting towards cleaner fuels, or increasing efficiency of driving behavior. With respect to the latter, Intelligent Transport Systems (ITS) are crucial to support a sustained improvement in driving behavior, since studies have found that 'eco-driving' initiatives have a lower-than-expected impact on long-term energy efficiency since drivers partially slip back to less environmentally friendly driving habits after training sessions. Devising ways to sustain the eco-driving behavior is therefore a crucial measure to consolidate the fuel consumption savings in the longer term and for management purposes of bus companies.

Here we propose a methodological procedure to micro-monitor the bus driver behavior and return both real-time feedback to the driver and a reporting mechanism for the bus line manager (which could be daily, weekly or monthly depending on the variability of the monitoring results). In the first case, the objective is to sustain the eco-driving behavior after training sessions. In the second, the aim is to detect persistent situations of low energy efficiency along the bus route.

The present paper is relevant for the conference and more specifically for the topic of Innovation in Transport Planning and Governance, since we propose a means of increasing energy efficiency of Public Transit and thus environmental performance, also, by using ITS (on-board real-time logging device) for guiding bus drivers behaviour and provide detailed data for the bus line managers.

Regarding the methodological approach, we look at a long-term bus monitoring campaign that registers driving patterns (including several events like acceleration/deceleration, open-door times, idling times, among others) and instantaneous fuel consumption rates for a suburban route (which includes both urban and suburban-highway driving conditions). One bus was equipped with real-time logging equipment and was followed during 3 months to analyze the impact on fuel consumption and on different driving parameters (Note: the bus was driven by different drivers which had an impact in increasing the variability of results). After data collection and data mining procedures, we identified the most and less energy-efficient periods of the day for both directions of the route under analysis. For those critical periods, several analysis are conducted and different operating conditions are compared: 1) estimation of fuel consumption rates through a regression analysis model where the explanatory variables are average speeds (for few seconds timeperiods), acceleration/deceleration and route grades; and 2) identification of near-optimal circulation speeds along the bus route that minimize fuel consumption for different operating conditions (we note that real-time data acquisition does not take traffic flow conditions into consideration). Thereafter, a feedback mechanism for the bus drivers is suggested indicating less-than-efficient driving behaviour. A reporting system is proposed for the bus line manager to monitor the corresponding energy efficiency, through chart building of several indicators based on the data previously collected and processed.

The key results obtained with the present research are:

- Fuel consumption regression models for different operating conditions and including the following independent variables: average speed, acceleration/deceleration, and grades.
- Identification of "near-optimal" average speeds along the bus line that minimize fuel consumption for specific operating conditions.
- Real-time feedback mechanism for guiding drivers towards a more efficient behavior.
- Reporting mechanism for the bus line managers.

**Keywords:** Fuel-efficiency, On-board real-time logging device, Fuel-efficient driving, Urban/suburban buses