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Operating conditions of buses in use in the Ile-de-France region of France for the evaluation of pollutant emissions

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Abstract

This study is intended to link the pollutant emissions from buses to their driving conditions and to the urban context. Envisaged in the case of the Ile-de-France region of France, this procedure constitutes a methodological basis for characterising bus networks by using geographic and bus operation databases.

Firstly, the bus routes are characterised by linking analyses of bus operating conditions and urban characteristics collected and managed by a Geographic Information System. This multidimensional analysis provides bus-route profiles according to the types of areas served.

Secondly, one vehicle of a bus route from each of the categories thus defined was instrumented in order to measure its operating parameters during commercial use. The parameters measured include engine operation, the speed and location of the vehicle, passenger load, load linked to the road profile, and electrical and pneumatic loads.

After outlining the methodological approach to network characterisation, a description is given of the instrumental protocol followed by the general results of the experiments. In all, over 25,000 km were recorded over 1600 h of driving, for which the main operating parameters were measured at time intervals of 1 s. Preliminary analyses (characterisation of urban areas) and the localisation of the recordings enable linking bus operating conditions with local specificities. The bus operating conditions (speeds, congestion, load, etc.) are analysed as a function of the routes and the geographical and urban specificities of the areas served.

This data is then analysed in order to formulate driving cycles representative of real traffic conditions and that serve as the basis for measuring the real pollutant emissions of buses on a vehicle test bench. These driving cycles will then enable associating pollutant emissions with the corresponding driving conditions and geographical areas.

Keywords: Vehicle; Traffic; Instrumentation; Speed; Driving cycle

1. Introduction

Pollutant emissions from road vehicles are strongly linked to vehicle use and operating conditions (Jensen, 1995; Sjödin et al., 1998; Hansen et al., 1995; Barlow and McCrae, 2001). The evaluation process generally

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requires in-depth analysis of these conditions and the development of representative measurement methods or test cycle (Austin et al., 1993; Newman et al., 1992; André, 2002).

The operating conditions of buses are above all linked to the urban environment through which they pass and their commercial operating conditions. Characterisation of this context should enable identifying the different types of operating conditions in order to measure real pollutant emissions. At a later stage, this information should enable us to predict the energy and environmental consequences linked to a given context and optimise energy reduction policies and reduce nuisances by assigning low-pollutant vehicles to the most unfavourable areas and by optimising bus routes.

To achieve this, a study was carried out on RATP bus routes (RATP: Régie Autonome des Transports Parisiens is the largest bus company providing routes in Paris and its suburbs) within the greater Paris area due to the wealth of available data. The method consists in characterising the urban bus network in monitoring the operating conditions of the bus in use, and finally in building-up representative driving cycles according to the urban context. This scheme is applicable to the study of other networks, though subject to the availability of urban geographical and bus operating data.

2. Characterisation of a bus network and selection of representative bus lines

Kenworthy et al. (1992) and Newman et al. (1992) analysed traffic conditions for private cars in a city, using the concept of urban ecology, i.e. the study of the different characteristics (form and function) of a town considered as a system. Papayannakis (1998) considered the problem of the territorial modelling of traffic on bus routes according to ''socio-urbanistic'' parameters (population, employment, housing, buildings, infrastructure, access to the transport means, public transport, etc.).

Considering that vehicle operating conditions are first of all dependent on the ''urban context'', we analyse the context in which the buses travel by using data on population, employment, housing, road network, traffic, and the areas served (schools, stations, retail outlets, etc.) and crossed (André and Villanova, 2002, 2004). This data is calculated for the Ile-de-France region divided into 225,000 units of $100 \times 100\,m^2$ and stored in a Geographical Information System (GIS). This is completed by bus route characteristics and operating statistics (dedicated bus lanes, the number and types of bus stops, commercial speed, number of passengers, fluctuations linked to congestion, accidents, specific features in passenger load, areas served and specific connections, etc.). We also define a remoteness rating corresponding to the sum of the distances (reduced by their average value) to the activity centres (schools, stations, shops).

The factorial analysis of these geographical units and classification enables establishing a typology of areas in 12 classes. The main parameters of differentiation are density and housing type, types of lanes, and the level of traffic (Table 1). In this way, the conurbation is ''zoned'' into: low population level, houses, remoteness from facilities, intermediary areas of isolated houses, mixed and dense housing, areas near major roads that associate very dense housing, dense Parisian and suburban town centres.

Bus routes cross and serve these different areas (Fig. 1), thus they are analysed according to their itineraries through the types of area. As the previous steps considered cells of $100 \times 100\,m^2$ and aggregated parameters (describing the road network, the housing, the population, the equipments) which already integrates an influence zone, we consider then the strict intersection of the bus line with the cells and not a band around it.

Using a similar process (factorial analysis and clustering), we define five main categories of line characterised by their itineraries and operating conditions (Table 2):

- Seventy-three lines (34% of the network in distance), that use the main road network with high levels of traffic and serve dense town centres. These lines travel at $14\,km\,h^{-1}$ on average and have relatively high service irregularity rates[1]. Route 163 connecting Paris to the nearby Northwest suburb is representative of this group and will be chosen for the experiment.
- Thirty-two lines (15% of the network) connecting mixed or isolated housing areas. This class is well represented by the mixed line 206 and 207 (from Noisy-Le-Grand to La Queue-en-Brie or to Pontault-Combault) serving the more remote suburbs to the east of Paris.
- Fifty-two lines (25% of the network) serve dense mixed and individual housing areas. This category is characterised by line 319 which connects the Massy Palaiseau RER (high speed metro) station to the International Market of Rungis in the remote southern suburb.
- Fifty-five lines (21% of the network) mainly serving Paris and high-density housing areas. These lines travel at an average of $11\,km\,h^{-1}$ and have the highest rates of service irregularity and accidents. Line 47 (Gare de l'Est – Kremlin-Bicêtre) was chosen to represent this class.
- Six atypical long and rapid ($28\,km\,h^{-1}$) lines serving airports and RER stations and using motorways. These routes have not been included in the current investigation.

[1]The irregularity rate is defined from timetable variations of passage at different points on the bus line.