Transportation Research Part A 63 (2014) 93–106

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Are HOV/eco-lanes a sustainable option to reducing emissions in a medium-sized European city?

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ARTICLE INFO

Article history:
Received 28 November 2012
Received in revised form 4 March 2014
Accepted 10 March 2014
Available online 5 April 2014

Keywords:
Integrated simulation
Microscopic traffic model
Instantaneous emission model
Emissions
Eco-lanes
HOV

ABSTRACT

Innovative traffic management measures are needed to reduce transportation-related emissions. While in Europe, road lane management has focused mainly on introduction of bus lanes, the conversion to High Occupancy Vehicles (HOV) and eco-lanes (lanes dedicated to vehicles running on alternative fuels) has not been studied comprehensively. The objectives of this research are to: (1) Develop an integrated microscopic modeling platform calibrated with real world data to assess both traffic and emissions impacts of future Traffic Management Strategies (TMS) in an urban area; (2) Evaluate the introduction of HOV/eco-lanes in three different types of roads, freeway, arterial and urban routes, in an European medium-sized city and its effects in terms of emissions and traffic performance. The methodology consists of three distinct phases: (a) Traffic and road inventory data collection; (b) Traffic and emissions simulation using an integrated platform of microscopic simulation; and (c) Evaluation of scenarios. For the baseline scenario, the statistical analysis shows valid results. The results show that HOV and eco-lanes in a medium European city are feasible, and when the Average Occupancy of Vehicles (AOV) increases, on freeways, the majority of vehicles can reduce their travel time (2%) with a positive impact in terms of total emissions (−38% NO_x, −39% HC, −43% CO and −37% CO_2). On urban and arterial corridors, the reduction in emissions could be achieved only if the AOV increases from 1.50 to 1.70 passengers/vehicle. Total emissions of the corridor with an AOV of 1.70 passengers/vehicle can be reduced up to 35–36% for the urban route while the values can be reduced by 36–39% for the arterial road. With the introduction of Hybrid Electric Vehicles (HEV) and Electric Vehicles (EV) it is possible to reduce emissions, although the introduction of eco-lanes did not show significant reductions in emissions. When both policies are simulated together, an emissions improvement is observed for the arterial route and for two of the scenarios.

1. Introduction and objectives

The first objectives of Traffic Management Strategies (TMS) deployments were commonly focused on improving safety, relieving congestion and saving costs (Barth and Boriboonsomsin, 2009; Gkritza and Karlaftis, 2013a, 2013b;

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http://dx.doi.org/10.1016/j.tra.2014.03.002
0965-8564/

Shladover, 2011). However, since the urban traffic is responsible for 70% of local pollutants emissions and 40% of CO_2 emissions, there has been a growing emphasis on environmental concerns (EC, 2007). In this context, the projects eCoMove (Europe) and AERIS (USA) are examples of integrated approaches to help travelers to use the infrastructure more efficiently (Vreeswijk et al., 2010; US DOT, 2012).

One of the most common strategies to increase the efficiency in the use of infrastructures is to maximize the average vehicle occupancy rates by providing incentives to the use of the so-called High Occupancy Vehicles (HOV) (Mateos et al., 2004). While HOV lanes have been widely applied in USA, currently there are few examples of HOV lanes in operation in Europe (Mateos et al., 2004). Nevertheless, in the late 90s, cities such as Leeds, Brussels, Graz or Madrid have incorporated HOV lanes either in highways or in urban arterials. Although these case-studies have demonstrated that the introduction of HOV can be an effective way to promote car-pooling (Haugen, 2004; UFB-ITS, 1999), the environmental impact of this strategy is unclear. The majority of studies on HOV lanes impact on emissions were carried out based on American study-cases. Previous research focuses on the effect of adding new HOV lanes in the network (Johnston and Ceerla, 1996), lane conversion between mixed flow and HOV, and HOV lane configuration (Boriboonsomsin and Barth, 2008).

Recently, the concept of eco-lane has become an instrument to incentivize the purchase of vehicles that would be better for the environment (US DOT, 2012). However, with the exception of Boriboonsomsin and Barth (2008), previous analysis of the HOV/eco-lanes impact on emissions typically uses modal emissions models based on average speeds and traffic volumes. The increase in computing performance has yielded more practical use of microscopic traffic models which can track individual vehicle movements on a second by second basis, allowing a more refined analysis and improve the accurateness of the total emission estimations. The outputs of these models as speed and acceleration can be used in instantaneous emissions models. These emission models can be used to evaluate the consequences of different traffic management policies applied to the road network, such as lanes management, traffic signal coordination, route diversion, variable speed limits, and Advanced Traffic Information Systems (Aziz and Ukkusuri, 2011).

Table 1 summarizes the most relevant studies that linked microscopic traffic models with external emissions models. In addition to the main variables analyzed and highlights of each study, the following data is provided: case study, scale, traffic model, and emissions model. The majority of the studies linked PARAMICS and VISSIM traffic models with CMEM or MOVES emissions models, while other studies integrated different traffic models such as Dracula, AIMSUN, INTEGRATION or UMTS with Mobile, EMFAC, VT-micro and ENVIVER emission models (Jackson and Rakha, 2011; Int Panis et al., 2006; Zhang et al., 2009a; Csikós and Varga, 2012). Song et al. (2012) found that VISSIM model tends to produce more aggressive acceleration and deceleration than in real-world. However, the large majority of the studies did not assess the capability of the traffic models to capture the real-world vehicle power distributions.

The literature review shows that the large majority of studies that linked microscopic traffic simulation models with instantaneous emissions models did not use real world data on vehicle dynamics to assess if the model output is consistent with real world traffic. Regarding the implementation of HOV lanes, and namely in the European context, there is a lack of knowledge about the emission impact of this measure in different types of roads, different Average Occupancy Vehicle rates (AOV) and eligible vehicles. Moreover, the available knowledge about the impact of eco-lanes on emission is very limited. Thus, the main objectives of this research are:

1. Assess the impact of future TMS in an urban area of a medium-sized European city using an integrated simulation platform of a microscopic road traffic and an instantaneous emission model, calibrated with real world data.
2. Evaluate the introduction of eco-lanes in different types of roads (freeway, arterial and urban roads), and its effects in terms of emissions and traffic performance.

2. Methodology

Fig. 1 shows the main steps of the methodology developed in this study. Firstly, data on vehicle dynamics, traffic volumes, traffic signals timing and AOV were collected to evaluate the microscopic traffic (VISSIM) and an instantaneous emissions model (the Vehicle Specific Power – VSP) for the baseline scenario. After that, several scenarios related with the introduction of eco-lanes will be evaluated in order to compare the use of these TMS in different types of routes. For Hybrid Electric Vehicles (HEV) emissions estimation, a modal emission model (CORINAIR) was used.

Next, the study domain (see Section 2.1) is presented, as well as the traffic (see Section 2.2) and the emission (see Section 2.3) tools. Then the process of calibration and validation used to evaluate the baseline scenario is displayed (see Section 2.4) and finally a description of several eco-lane scenarios is presented (see Section 2.5).

2.1. Study domain

Studies conducted in medium-sized cities show that traffic problems are not just phenomena of the large metropolis (EFILWC, 2008). One typical problem is that population densities are not high enough to support efficient public transportation, further increasing the demand for individual transport. To evaluate the impact of TMS measures in a medium-sized city, this research was conducted in Aveiro (Portugal). This is a representative case of a European medium-sized city with 78,500 inhabitants (INE, 2012) and with developed commercial and touristic activities. Previous empirical research carried out in this area have addressed the impact of route choice in terms of emissions (Bandeira et al., 2012, 2013). Moreover, in