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Eco-driving key factors that influence fuel consumption in heavy-truck fleets: A Colombian case

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ABSTRACT

This research identifies key variables that influence fuel consumption that might be improved through eco-driving training programs under three circumstances that have been scarcely studied before: (a) heavy- and medium-duty truck fleets, (b) long-distance freight transport, and (c) the Latin American region. Based on statistical analyses that include multivariate regression of operational variables on fuel consumption, the impacts of an eco-driving training campaign were measured by comparing ex ante and ex post data. Operational variables are grouped into driving errors, trip conditions, driver behavior, driver profile, and vehicle attributes.

The methodology is applied in a freight fleet with nationwide transport operations located in Colombia, where the steepness of its roads plays an important role in fuel consumption. The fleet, composed of 18 trucks, is equipped with state-of-the-art real-time data logger systems. During four months, 517 trips traveling a total distance of 292,512 km and carrying a total of 10,034 tons were analyzed.

The results show a baseline average fuel consumption (FC) of 1.716 liters per ton-100 km. A different logistics performance indicator, which measures FC in liters per ton transported each 100 km, shows an average of 3.115. After the eco-driving campaign, reductions of 6.8% and 5.5% were obtained. Drivers' experience, driving errors, average speed, and weight-capacity ratio, among others, were found to be highly relevant to FC. In particular, driving errors such as acceleration, braking and speed excesses are the most sensitive to eco-driving training, showing reductions of up to 96% on the average number of events per trip.

1. Introduction

In 2014, oil represented 31% of the total global primary energy supply, representing 34% of the global CO_2 emissions (IEA, 2016). At the same time, transportation represented 23% of these emissions, with a noteworthy 71% increase since 1990. This pollution growth was mainly driven by the road sector, which represented three quarters of the transport emissions, including the heavy-truck industry, which moves a huge portion of the freight worldwide. In 2014, Latin America represented 4% of global CO_2 emissions and

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Table 1
Relevant issues covered by the recent eco-driving literature.

Author	Variables							Scope			Analysis and results features							
	VP	VE	Em	RC	LE	DC	DP	DS	Urb	LD	LS	SM	ER	MR	Frg	RT	Place	*Others
Current research	•			•	•	•	•			•		•	•	•	•	•	Colombia	
Ayyildiz et al. (2017)	•	•	•		•				•			•	•	•	•	•	China	
Xu et al. (2017)	•	•	•	•		•			•				•	•		•	U.S.	b
Ma et al. (2015)	•	•			•	•			•				•			•	China	
De Abreu e Silva et al. (2015)	•			•		•	•		•		•	•	•*	•		*	Portugal	b, d, e
Walnum and Simonsen (2015)	•			•	•					•		•	•*	•	•	*	Norway	d, e
Lai (2015)							•		•			•	•	•		*	Taiwan	s
Sullman et al. (2015)	•							•								*	UK-Finland	b, s
Rolim et al. (2014)							•		•		•		•	•		•	Portugal	b
Caulfield et al. (2014)			•	•	•		•		•		•	•	•	•		•	The Netherlands	
Birrel et al. (2014)	•								•			•	•				Several	
Wåhlberg (2007)	•				•		•		•				•			•	Sweden	b
Stromberg and Karlsson (2013)							•		•		•		•			*	Sweden	b, s
Delhomme et al. (2013)							•		•			•	•			*	France	s
Beusen et al. (2009)	•								•			•	•			•	Belgium	
Rutty et al. (2013)	•		•						•				•			•	Canada	
Ando and Nishihori (2012)			•				•		•			•	•			•	Japan	
Liimatainen (2011)	•			•					•			•	•	•		*	Finland	b, s

VP: vehicle parameters.
VE: vehicle or engine models.
Em: emissions.
RC: road/route infrastructure & traffic conditions.
LE: load and weight effects.
DC: driving cycles/route.
DP: driver profile.
DS: chassis dynamometers tests or simulations.
Urb: urban or suburban.
LD: long distances.
LS: feedback logging systems effects.
SM: statistical models/hypothesis tests.
ER: empirical results.
MR: managerial recommendations.
Frg: freight transport.
RT: real time data.
Comments: b: buses, d: daily data, s: surveys, e: elasticity.

presented a 98.1% increase in emissions from fuel consumption (FC) since 1990 (IEA, 2016). Consequently, countries such as Colombia show a huge dependence on fossil fuels at 76% of the total energy consumption (World Bank, 2017), and more than 90% of CO_2 emissions by the transportation sector originates from road transport (IDEAM, 2016), of which 50% is due to freight transport (MinTransporte, 2014). To counteract this finding, eco-driving has emerged as one of the most effective strategies to decrease fuel consumption and emissions, showing savings that range from 0% to 18% (Stromberg and Karlsson, 2013; Rutty et al., 2013; Xu et al., 2017).

Sanguinetti et al. (2017) have identified six classes of eco-driving actions: driving, cabin comfort, trip planning, load management, fueling, and maintenance. This research focuses on the driving class, in which eco-driving training programs for drivers are the key enabler to enhance safer driving and lower fuel consumption. The training is conceptual and practical to ensure knowledge transfer to drivers, but their success depends on how firms incorporate assessment tools and metrics to maintain eco-driving styles for their drivers. Further details about eco-driving techniques are briefly noted by several researchers (see Wåhlberg, 2007; Birrel et al., 2014).

There is a vast body of literature concerning fuel consumption and energy efficiency estimates in vehicle fleets. Diverse approaches exist to understand and analyze the relevant components of fuel-economy functions that are part of vehicle-engine models (Mensing et al., 2014; Ma et al., 2015; Yu et al., 2016), driving-style-related models (Delhomme et al., 2013), selection and use of driving cycles (Mensing et al., 2014), and eco-driving assessments regarding their impact on emissions and fuel consumption (De Abreu e Silva et al., 2015). On the other hand, data validation methods vary from technically controlled tests on chassis dynamometers, to empirical and statistical analysis of real-world data acquired with specialized technologies. Table 1 shows a summary of key issues considered by recent studies related to eco-driving programs to assess and improve fuel consumption. Studies that focused on logging systems and feedback to users are excluded from this analysis; however, readers are referred to the literature review of Rolim et al. (2014) for further details on this specific topic.

The classification presented in Table 1 includes a first set of operational factors that have an impact on fuel consumption. These factors consist of vehicle parameters (i.e., vehicle attributes important for the fuel consumption such as weight, age, and power), route conditions (e.g., driving cycle, road conditions, and level of service), emissions (e.g., emission-based models), vehicle or engine