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Policy oriented emission factors for road freight transport

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ABSTRACT

Impact assessments of carbon emission mitigation policies by shippers and carriers require appropriate emission models and indicators of logistics activity. Usually, the ton-kilometer indicator is used to measure logistics activity, and emissions are calculated as a linear function of this indicator. Generally, the models that emission factors originate from are unknown. This makes their application difficult, especially when interdependencies between measures must be considered. Here, we develop a policy oriented framework of simplified emission factors that are derived from internally consistent, comprehensive models, are applicable to the various measures by different logistic actors and are as easy to use as the usual ton-kilometer indicator. We identify a set of emission factors by taking simple first order derivatives of two comprehensive models proposed in the literature, the EcoTransIT World Model and the Ligterink model. The approach allows us to compare the models and discuss the effectiveness of our framework for alternative mitigation strategies. We position the emission factors of the first as a specific case of the latter model and discuss the bounds of the applicability of emission factors from the two models.

1. Introduction

The transportation sector is a great contributor to climate change, accounting for as much as 22% of the energy related world GHG emissions (IEA, 2010). It represents the third largest GHG source within the UK in 2009 (DECC, 2010) and is responsible for 36% of the French national CO_2 emissions (CITEPA, 2011). In the context of climate change mitigation, the reduction of CO_2 emissions associated with transportation and logistics activities is an important challenge. Nevertheless, the objectives for emission reduction set at the supranational (United Nations, European Union) and national levels are most often general, not providing specific targets for the transportation sector. For example, the objective of the European Union to reduce their annual greenhouse gas emission by at least 20% by 2020 and by 80–95% by 2050, compared to 1990 emissions levels (EC, 2011), do not target specifically the transportation emissions. Besides, transport modes and purposes are not all considered equally. The Kyoto protocol does, for example, not include international transportation in its accounting framework (UNFCCC, 1998). This raises some questions of fairness, as maritime and air transportation have benefited so far from the absence of constrains related to their GHG emissions. Maritime and air transportation were found responsible for as much as, respectively, 11% and 2% of the GHG emissions, caused by the transportation of goods and associated with French consumption in 2004 (Hawkins and Dente, 2010). The biggest GHG emission share was associated with road transportation, as the main trade partners of France were in Europe. Road sector emissions indeed dominate transport emissions globally, notably due to its reliability and flexibility which makes it a privileged terrestrial transportation mode (ITF, 2010). Some

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countries (e.g. France, Germany and Japan) nevertheless stand out in that they have seen their road CO_2 emissions stabilized or decreased even before the recession of 2008–2009, despite economic and road freight growth over the same period. Fuel taxation in Germany, reduction of average traffic speeds in France and higher load factors in Japan are some of the explanatory factors of the observed decrease in GHG emissions (ITF, 2010). More recently, a 2012 French law has made the report of emissions by logistic providers compulsory (MEDDE, 2012). The objective of this regulation is to make CO_2 emissions part of the strategy of logistic service providers and to incite them to reduce their emissions. The reduction of CO_2 emissions is more and more often quoted as an important strategic target by logistic companies in their activity or sustainability reports: DHL green services (Germany) are for example targeting to become 30% more carbon efficient by 2020 compared to a 2007 baseline (DHL, 2011); the SNCF group (France) proposes an absolute reduction of 15% of the rail traction energy between 2012 and 2022, with an intermediate objective of 7.22 gCO_2/Tkm for 2020 (SNCF, 2013).

The reduction of GHG emissions of transportation is thus heavily dependent on the implementation of transportation policies and of the willingness of logistic service providers to make GHG emission an element of competition within the logistic system. An important prerequisite is the availability of tools to measure and calculate the effects of emission reduction measures. For this purpose, logistic providers have developed their own calculation tools, resulting in a high variation in CO_2 emissions calculations for similar situation. Within Europe, an attempt to reply to this lack of standardization was the introduction of the European norm EN 16258. Despite this, efforts remain needed to organize and classify the diversity of existing emission models and associated indicators. Guidelines such as those recently developed by (Schmied et al., 2012), to help calculating emissions for freight forwarding and logistics services in accordance with EN 16258, are needed. Similarly, reviews of emission models are needed to understand their use of logistic parameters and the limits of their applicability to logistics issues. Reviews of emission models were made by Williams et al. (2012) and Demir et al. (2014). The latter classified factors affecting fuel consumption into five categories: vehicle, environment, traffic, driver, and operations. In the literature, several generic emission models have been proposed, including many factors influencing fuel consumption but ignoring interdependencies between these factors. These generic emission models include standardized, generic emission factors measured in gCO_2/Tkm or gCO_2/km. More complex emission models (NTM, 2010; Ligterink et al., 2012; Knörr et al., 2014) require detailed operational data and therefore are not easily applied in policy analysis.

In this paper, we propose an approach to create simplified emission functions for road freight transport based on comprehensive emission models. The approach entails the derivation of a set of interdependent emission factors. We demonstrate the approach for two recent comprehensive models proposed in the literature, the EcoTransIT World Model and the Ligterink model. We compare results of our simplified functions with the results of the original models and demonstrate their use to study the effectiveness of alternative emission mitigation strategies.

The paper is organized in three sections. The next section introduces the theoretical framework and presents the derivation for each emission model. Section 3 compares our framework of factors for the two models and compares the results with calculations from the original models in an application for different greening strategies. Also, we discuss the bounds of the validity of the factors. Section 4 summarizes our results and concludes the paper.

2. Modeling approach

Emission models can be defined following Eq. (1) as a function based on a set of parameters p_i. As described by (Demir et al., 2014), a first distinction between parameters is based on their microscopic or macroscopic character, noted here respectively h and H. Macroscopic parameters corresponds to aggregate network parameters, such as the use of a road gradient classified by road category, instead of the actual one. On the opposite, microscopic parameters correspond to instantaneous network parameters that require intensive measurements. The second distinction we propose here is between parameters that are modifiable by the model user and those which are not, noted respectively s and f. We thus define four categories of parameters: the microscopic modifiable parameters (sh), the macroscopic modifiable parameters (sH), the microscopic fixed parameters (fh) and the macroscopic fixed parameters (fH). Eq. (1) is thus transformed in Eq. (2) in which J, K, L, O represents the number of parameters belonging to each category respectively and N the total number of parameters.

$$CO_2 = f(p_1, \ldots, p_N) \tag{1}$$

$$CO_2 = f\left(p_1^{sh}, \cdots, p_J^{sh}, p_{J+1}^{sH}, \cdots, p_{J+K}^{sH}, p_{J+K+1}^{fh}, \cdots, p_{J+K+L}^{fh}, p_{J+K+L+1}^{fH}, \cdots, p_N^{fH}\right) \tag{2}$$

Emission models are thus now described by a double specificity. Indeed, the more microscopic parameters are used, the more emission models can calculate emissions corresponding to varying specific situations. The side effect of this capability is the resulting need for data collection and management, as microscopic data are instantaneous and thus continuously changing during transport execution. Actor specificity reveals the parameters for which the carrier or shipper can develop an emission mitigation strategy. We can thus define two ratios describing specificity. First, the ratio (J + L)/N, noted R_1, describes the situation specificity of the emission model. Then, the ratio (J + K)/N, noted R_2, describes the actor specificity. The closer R_1 is to 1, the more situations can be described at the conditions of having a sufficient detailed database. The closer R_2 is to 1 and the more the emission model suits the actor purpose. Actors should thus choose in prioritizing models for which R_1 and R_2 are high. Following Eq. (2), we now analyze the variation of the emission function through a Taylor expansion at the first order. Since actors can only modify the first J + K parameters of Eq. (2), the Taylor expansion is only applied to

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